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Modeling Soviet Modernization: Prospects for Economic Growth

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A Technical Intelligence Report

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Modeling Soviet Modernization: Prospects for Economic Growth

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A Technical Intelligence Report

This paper was prepared by
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Modeling Soviet Modernization: Prospects for Economic Growth [redacted] 25X1

Scope Note

Information available as of 8 September 1987 was used in this report.

This paper uses a macroeconomic model of the USSR to evaluate prospects for Soviet economic growth to the year 2000. Because of the considerable uncertainty regarding the ultimate success of General Secretary Gorbachev's modernization and reform program, and because of the long time frame of the projection, a single "most likely" forecast cannot be made. Instead, three scenarios were constructed to reflect different degrees of success for Gorbachev's initiatives. The results of these simulations provide insights into what is possible and illustrate the dynamics involved when an economy administered by central planners for nearly 70 years attempts to change its method of operation. [redacted] 25X1

This is a technical paper that presents the results of the simulations, provides a description of the model used to obtain those results, and documents the underlying assumptions. The traditional version of CIA's model of the Soviet economy—SOVSIM—was originally designed to project GNP growth during periods of relative stability in the relationship between inputs (capital and labor) and output. Because Gorbachev's program attempts to sharply change this production relationship, it was necessary to substantially revise SOVSIM before the analysis. The paper discusses the major revisions and the rationale for them. [redacted] 25X1

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Modeling Soviet Modernization: Prospects for Economic Growth [redacted] 25X1

Summary

General Secretary Gorbachev's program to modernize the Soviet economy is intended to sharply change longstanding relationships between inputs (capital and labor) and output that will alter the growth path of the economy during the rest of this century. His modernization and reform program represents the most intense and comprehensive effort to address Soviet economic problems in decades. Its aggressive implementation, in fact, is causing serious disruptions and turbulence in the economy and is expected to cause more as the bureaucratic factions attempt to adjust to the many changes being imposed from above:

- Gorbachev's quality control program is disrupting production and the supply network as poor-quality goods are rejected.
- New initiatives in organization and management are creating confusion and apprehension in some quarters, and bureaucratic foot-dragging and outright resistance in others.
- The rapid pace of the reform program imposes a staggering set of tasks on the central bureaucracies and on the producing units, while simultaneously demanding fulfillment of the 12th Five-Year Plan (1986-90).
- The sharp reallocation of limited investment resources will undoubtedly lead to imbalances in production and new capacity. [redacted] 25X1

Capturing Policy Changes

To capture the effects of Gorbachev's policy changes, CIA's macroeconomic model of the Soviet economy (SOVSIM) was upgraded to take specific account of the modernization program. It was used to simulate Soviet economic growth prospects to the year 2000 under alternative assumptions about the success of individual elements of the program. We modified the model's production functions to:

- Distinguish between the productivity of new and old capital equipment emanating from the sharp change in investment policy, which was designed to foster the development and production of high-technology equipment (embodied technological change).
- Accommodate changes in labor's contribution to economic growth, originating from policies intended to improve skills and increase productivity.
- Account for economic disruptions that might result from the myriad changes to entrenched economic mechanisms and practices. [redacted] 25X1

The revised model enables us to take specific account of Gorbachev's initiatives in assessing the economy's potential growth path, but it does not enable us to see into the future any more clearly than did the traditional

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model. By using the revised model, however, we are able to isolate the effects on growth of alternative judgments about the success or failure of Gorbachev's main policies. 25X1

The Impact on Growth

The results of our simulations indicate that the Soviet growth goals of 4 to 5 percent per year—measured in real terms—are well beyond reach. Nevertheless, under the right circumstances, economic performance may be good enough for Gorbachev to declare his program a success. 25X1

If Gorbachev's program continues to be implemented vigorously the cost of adjusting to the new conditions will be a disruption that over the next few years could depress economic growth considerably below 2 percent per year. If, during this adjustment period, the leadership relaxes the pressure for quantitative gains in output in favor of stimulating higher quality, more efficient use of newer technology, and real decentralized decisionmaking, Gorbachev's policies could begin to take hold. This would bring higher returns to new capital equipment, an increase in the effectiveness and productivity of the labor force, and a progressive reduction in the economic disruptions of the adjustment period as the system adapts to the new conditions. Under this scenario—which we call "Gorbachev wins"—growth would accelerate in the 1990s. Although the 5-percent-per-year average that Gorbachev originally called for will not be reached, rates that would yield an average for the decade of about 3 percent per year are possible. More important, the mix of output would consist of higher quality and higher technology products. Although we believe Moscow would not be able to close the technological gap with the West under this scenario, it might narrow the gap in some key areas. 25X1

On the other hand, the period of economic disruption and slow growth could continue indefinitely if, for example, the system fails to adjust to the demands of Gorbachev's initiatives because of continued bureaucratic resistance, political conflict among the leadership, and frequent changes in objectives and directives. Under this scenario—which we call "Gorbachev loses"—growth would probably remain depressed throughout the 1990s, and the technological gap between the USSR and the West would widen appreciably. Under these conditions, Gorbachev might well suffer the same fate that befell Nikita Khrushchev in 1964. 25X1

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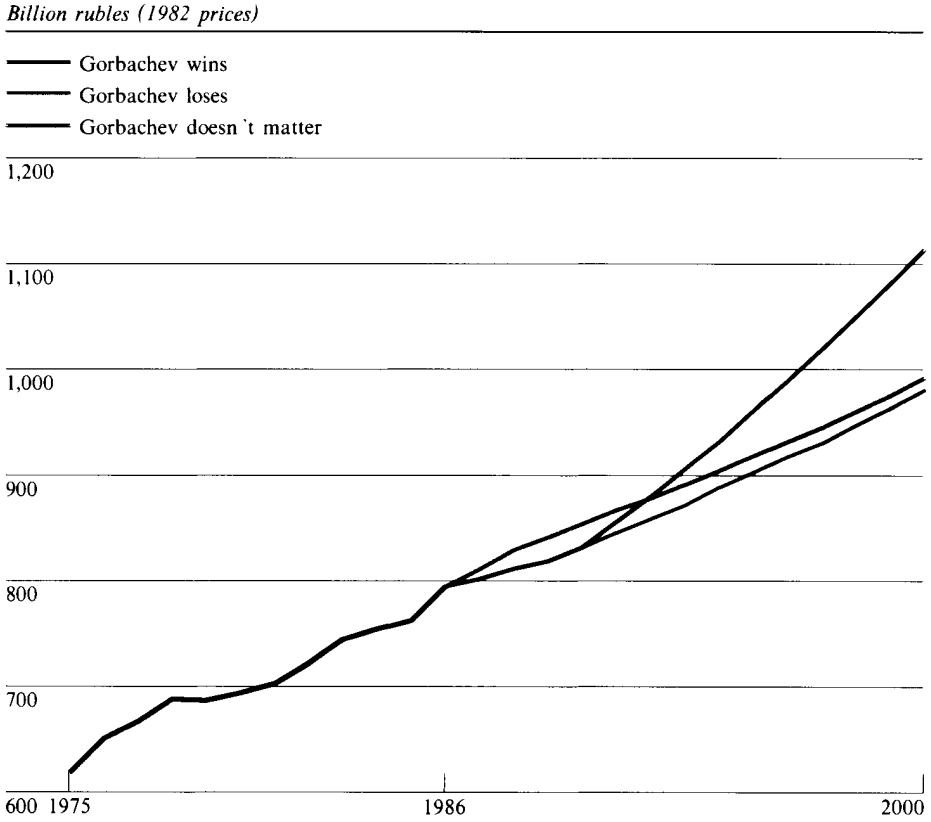
Figure 1
Projections of Soviet GNP



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Finally, if Gorbachev's program is not vigorously implemented—piecemeal reforms continue to be watered down by political compromise and central control over prices, resources, and production plans remains supreme—there probably would be very little change in the way the system operates or in its growth pattern. Under this scenario—which we call "Gorbachev

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doesn't matter"—the disruptions of an adjustment period would be avoided, and growth would be somewhat higher during the next few years than we would expect under either of the other scenarios. But there would be virtually no chance of acceleration in the 1990s, the mix and quality of goods produced would remain obsolete by Western standards and Soviet expectations, and the technology gap would undoubtedly widen in most areas.

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There are, of course, possibilities for Soviet economic growth other than those presented above. Gains from the modernization drive may be more or less than those simulated in the scenarios; the costs of adjustment associated with those gains may vary; and factors outside Moscow's control can affect economic growth. The outcome will depend not only on the specific nature of the reforms but also on how the reforms are implemented. It is not clear whether the regime will have the will—or ability—to sustain the modernization drive when faced with inevitable near-term reductions in growth that will result from Gorbachev's efforts to change the way the economy operates.

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Fighting To Win

Although we cannot predict with confidence the extent to which Gorbachev will "win" or "lose," we believe he will not let his program be viewed as a failure without a major struggle. He fought long and hard to get his new reform program ratified at the Central Committee plenum in June, and he will fight equally hard for implementation. These reforms could bring increased competition among state enterprises and a major decentralization of the price and supply systems that allows suppliers to deal directly with customers at prices determined through negotiations. Implementing such changes, however—even without political and bureaucratic resistance—will be difficult. Market mechanisms cannot be easily mixed with the command elements of a socialist system. Even the gradual introduction of markets would upset the delicate balance of the flow of goods and materials required by the command allocation of resources.

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Nevertheless, because the long-run impact of his policies has considerable potential for improving Soviet economic performance in the 1990s, Gorbachev is likely to stay the course. Most of the leadership is likely to support him and probably will be willing to wait for results; they will be less

concerned with near-term growth rates and more concerned with producing higher quality products, stimulating more efficient use of new technology, and promoting some real decentralized decisionmaking. Although Gorbachev's success could be undone by external events, he is working hard to ensure that the external environment will be favorable to his programs:

- *Reduced tensions in international relations.* Gorbachev is working hard at forging new relationships with the West, reviving ties to China, and maintaining the loyalty of client states in the Third World. Success in this effort would provide the breathing space necessary for redistributing resources to the civilian economy and acquiring the necessary equipment and technology, as well as for promoting a positive climate at home for his reform program.

- *Forward movement in arms control.* Arms control probably will not yield significant economic dividends in the near term, but it might prevent an expanding arms competition that could be increasingly costly. A successful arms control program probably would allow continued restraint in the growth of defense programs, providing additional resources for industrial modernization.

- *Continued Western commercial interest in East-West trade.* Eventual access to the vast Soviet market is the bait that continues to attract Western businessmen to the USSR. Recent reforms in the foreign trade apparatus, the ability of some Soviet enterprises to negotiate directly with foreign firms, the expansion of joint ventures, and increased interest in participating in international organizations—such as the General Agreement on Tariffs and Trade—increase the attractiveness of the USSR as a trading partner. This may provide Moscow with valuable access to Western products, particularly machinery and technology.

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Outlook

On balance, we expect some real progress to occur, particularly if meaningful economic reforms can be implemented and sustained without an accompanying political upheaval. But, because movement in the direction of reform will be painful and risky for many in the leadership and the bureaucracy, the progress will be slow and incremental. Even if

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everything goes right and Gorbachev "wins," the gains from developing (or acquiring) and using new technology as well as from creating a more productive labor force are not likely to come quickly enough or in large enough doses to significantly narrow the technology gap with the West during the remainder of this century. Substantial gains could occur in selected areas, especially those related to defense, but it will take years, perhaps even decades, of application and experience with new industrial processes, management techniques, and incentive structures before the Soviets would be able to match the rate of advance in industrial technologies that is becoming commonplace in the West.

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Gorbachev's Modernization Strategy

Since becoming General Secretary in 1985, Gorbachev has gradually put forward the most comprehensive program for economic modernization since Khrushchev.[2] The program is a combination of management reform, investment strategy, and human factors. Although parts of the program have already been put into place, the bulk of Gorbachev's "new economic mechanism" will not be fully implemented until after the start of the 13th Five-Year Plan in 1991.[3]

Plans to increase the productivity of labor and capital are at the core of the program. Because the labor supply is determined largely by demographic factors that are not under Moscow's direct control, the leadership has initiated education reforms, wage reform, an antialcohol campaign, and a discipline campaign—all designed to increase the quality and productivity of labor. Similarly, Gorbachev's capital modernization initiatives include programs to increase the quality of new capital, as well as the technology of production embodied in the machinery and equipment that comprise the new capital. But Moscow faces a very difficult challenge, because centrally planned economies are not well suited to change. There are no "automatic" mechanisms to bring supply into balance with demand when the methods of production and the composition of output change. Moreover, there is a high risk that planning mistakes during adjustment periods will result in decreases in economic efficiency that could create disruptions in producer-supplier relations and, in turn, retard economic growth.

[3] In his plenum report of 26 June 1987, Gorbachev said: "The radical reform of the system of economic management is not a single act but a process for whose completion a certain amount of time will be needed. . . . We must enter the 13th Five-Year Plan with a new economic mechanism, although its development will continue even in the following five-year plan."

Capital Modernization Program

An important feature of Gorbachev's game plan for revitalizing the economy is his program for modernizing the industrial capital stock. His plan calls for substantially increased investment growth targeted principally at the machine-building sector—the carrier of new technology. The intent of this new strategy is to renew the capital stock by a combination of high rates of investment and increased rates of retirement of old plant and equipment.[4] Because the existing stock of fixed capital is so large, however, its renewal cannot be accomplished within a single five-year plan period.

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Higher rates of growth of investment represent the quantitative dimension of Gorbachev's program, but the qualitative dimension is more important. The returns to new investment depend heavily on the technological level of the new plant and equipment being installed and the efficiency with which it is used. Specific aspects of the program to increase the technology level include:

- Creating interbranch scientific and technical complexes to expedite development and assimilation of new technologies into the machine-building production base.
- Increasing expenditures for science—a rough indicator of the resources committed to research and development (R&D)—by 35 percent during the current five-year plan, as compared with the 11th Five-Year Plan period.

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[4] Plans for the 12th Five-Year Plan (1986-90) call for an 80-percent increase in investment in the 11 civilian machine-building ministries, compared with the 11th Five-Year Plan (1981-85). The retirement rate of productive fixed capital is slated to rise from 1.8 percent in 1985 to 3.1 percent in 1990, while the retirement rate for the machinery component of productive fixed capital is to climb from 3.2 percent to 6.2 percent. (In Marxist parlance, productive capital is used directly in the production process. Nonproductive capital includes capital in the housing and municipal services sector and in organizations and institutions of public health, education, science, culture, art, credit institutions, and administrative organs.)

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- Introducing a new system of quality control—known as state acceptance—to put teeth into Gorbachev's plan to improve product quality.[5]

- Increasing dramatically the supply of more technologically advanced equipment. For example:

  — Production of robots in the current five-year plan is to increase by 120 percent, numerically controlled machine tools by 90 percent, and machining centers by 330 percent, compared with production in the 11th Five-Year Plan period.

  — Production of personal computers is to reach 1.1 million per year by 1990, compared with almost none through the mid-1980s.

But to stimulate the introduction of new technology and the production of better products requires the enthusiastic efforts of enterprises and research and development institutes. In shaping the organization and administration of the economy, Gorbachev is searching for a combination of organizational changes and economic levers that will encourage this kind of initiative at lower levels, while permitting control to be maintained from the center. Former Soviet leaders, including Khrushchev and Brezhnev, had similar goals but could not find the formula, or rejected it after seeing its implications of a diminished role for the party. It is clear from the results of the USSR's Central Committee plenum in June 1987 that Gorbachev intends to go well beyond the tinkering that characterized the Brezhnev economic reform decree in 1979 and the experiment in industry introduced under Andropov and Chernenko.[6]

[6] Gorbachev's major achievement at the plenum was the approval of a landmark program for comprehensive economic reform that would—if fully implemented—reduce central control over economic activity and provide a wider scope for market forces. Also approved were 11 draft decrees detailing changes in major sections of the economy, and a new law on enterprises designed to expand their decisionmaking powers and to force them to be financially responsible for their activities.

Labor Force Strategy

The success of Gorbachev's program will largely depend on the performance of the work force. A combination of measures is being implemented to strengthen discipline, improve labor utilization, enhance worker incentives, and provide more skilled labor. These measures represent the human factors in Gorbachev's program. 25X1

Discipline and Antialcohol Campaigns. The campaign for labor discipline, which was initiated by Andropov and foundered somewhat under Chernenko, has been revived in a new form. Workers at all levels are being told they could lose their jobs if they don't perform. The antialcohol campaign scored initial successes, sharply cutting alcohol consumption and thereby reducing drunkenness and absenteeism. Soviets credit these campaigns with helping to improve labor productivity in 1986.[8] 25X1 25X1

Efforts To Improve Labor Utilization. Moscow has long tried to improve labor utilization. Gorbachev has intensified this effort through a number of initiatives, including:

- *Work position certification.* Under this program, begun in 1985, all enterprises are tasked with a systematic inventory and evaluation of their labor and equipment—with the aim of eliminating low-productivity jobs and obsolete machinery. The inventory is also to provide planners with the information necessary to draw up regional balances in supply and demand for labor, and to more critically evaluate ministries' requests for labor.

- *Shchekino-type schemes.* Under these programs—variations on the experiment begun in 1967 in the Shchekino Chemical Combine—enterprises are assured a fixed wage fund and encouraged to release 25X1 25X1 25X1

[8] In his plenum report of 26 June 1987, however, Gorbachev admitted that the campaigns are now flagging, saying "in many places the momentum has been lost. . . . The incidence of drunkenness has increased again and idlers, parasites, and pilferers . . . again feel at liberty." 25X1 25X1

their least productive workers and use the resulting savings in wages to reward their most productive personnel. The Shchekino system is the basis for the wage reform (see the section "Wage Reform"), the new pay system recently introduced in scientific research institutes, and the staff-cutting scheme recently mandated for all Soviet railways. The Soviets expect these schemes to induce overmanned enterprises to release by 1990 up to 3.5 million workers for other jobs in the economy.

- *Mechanization.* Moscow hopes that the mechanization of labor intensive processes can free 20 million workers from manual labor by the year 2000. Five million manual workers are to be released during the current five-year plan period, as compared with a reported reduction of less than half that figure during the 11th Five-Year Plan period. This goal is to be realized largely through increased production of modern equipment.

Wage Reform. The implementation of a new wage system in Soviet industry began on 1 January 1987. The new system is designed to improve a worker's incentive to perform well and acquire advanced skills by reversing the longstanding trend toward wage leveling. Under the new system, sharply higher wage increases would go to those with skills vital to the modernization program—engineers, designers, and skilled labor in machine building. Wage increases are to be funded by the enterprises themselves through increases in productivity and savings in the wage fund created by releasing excess labor.

Education Reform. On 25 March 1987, Moscow adopted a program to overhaul the Soviet specialist training system, hoping to make it more responsive to the needs engendered by technological change and industrial modernization. The program calls for fewer but better trained graduates in engineering, in part through closer cooperation between industry and higher education. It includes tougher admissions standards, a more rigorous system of evaluating student performance, and special training for the best students. New curricula, texts, and teaching methods are to be developed by 1989. Schools are to reduce the number of specialties and provide a general scientific background, emphasizing independent study rather than rote learning, and practical training in enterprise-sponsored facilities. 25X1

Industry is called on to shoulder some of the burden of financing the educational improvements. Ministries and enterprises are to provide schools with use of staff and equipment and to provide funds to partially defray the training cost. These funds are to go for equipment to expand the computer education program and make badly needed improvements in educational facilities. 25X1

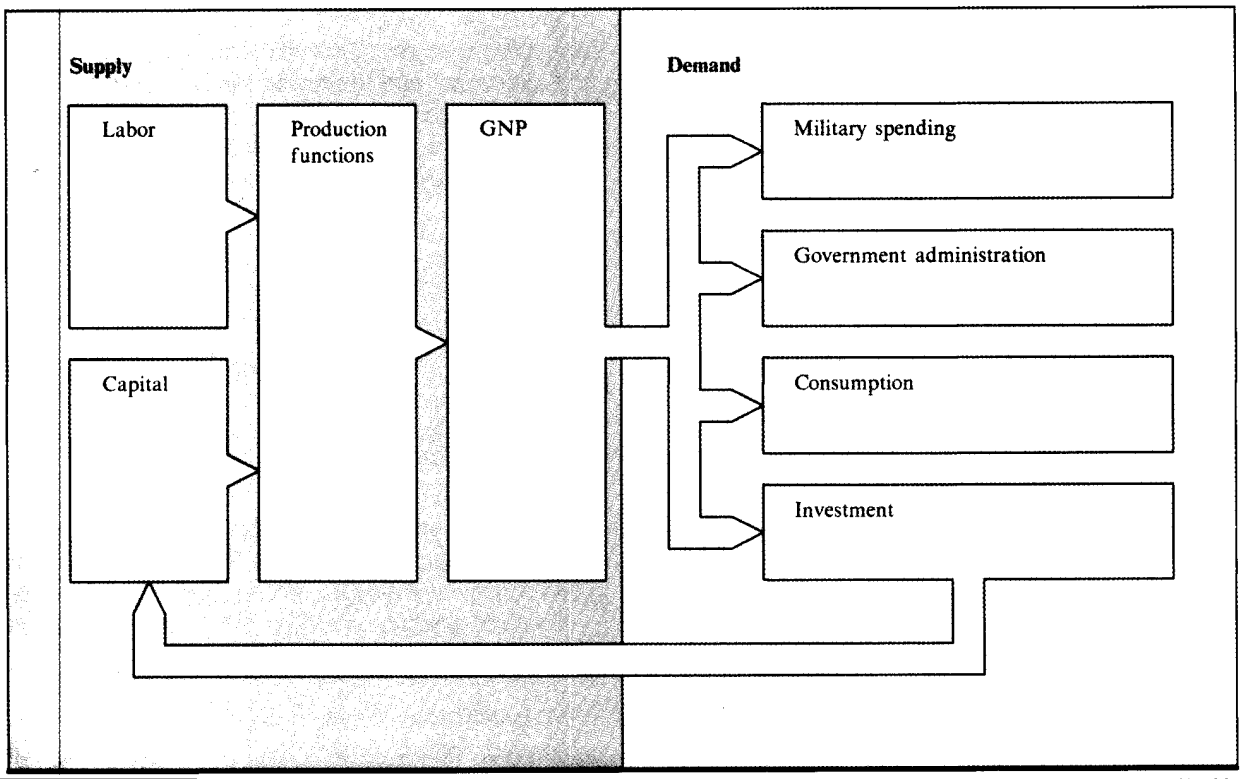
The Model

To capture the impact of Gorbachev's modernization program on our forecasts of economic growth, we modified CIA's macroeconomic model of the Soviet economy (SOVSIM)[9] to: 25X1

- Distinguish between the productivity of new and old capital equipment emanating from a sharp change in investment policy designed to foster the development and production of high-technology equipment (embodied technological change).
- Accommodate changes in labor's contribution to economic growth originating from policies intended to improve skills and increase the work effort.
- Account for economic disruptions that may result from a myriad of changes to entrenched economic mechanisms and practices. 25X1

The revised model enables us to take specific account of Gorbachev's initiatives in assessing the economy's potential growth path, but it does not enable us to see into the future any more clearly than did the traditional model. By using the revised model, however, we 25X1

Figure 2
Macroeconomic Model of the Soviet Union



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are able to isolate the effects on growth of alternative judgments about the success or failure of Gorbachev's main policies.

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Overview of the Model

The primary purpose of SOVSIM is to project the *real* growth of Soviet GNP (value-added measure in constant, factor-cost prices).[10] The model projects GNP by estimating net output according to the historical relationship between capital and labor inputs and output (see figure 2). Separate estimates of net output are made for each of 12 sectors of the economy.[11] Total GNP is estimated by summing the net output projections for the 12 sectors.[12] It is thus a

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[10] The principal conceptual difference between GNP and Soviet reported national income is the latter's exclusion of (1) most services (for example, health, education, housing, personal transportation and communications, recreation and personal care, government administration, credit and insurance, research and development, and military personnel costs); and (2) depreciation on fixed capital. For a discussion of the methodology for constructing national economic accounts for the Soviet Union along Western lines, see Joint Economic Committee, US Congress, *USSR: Measures of Economic Growth and Development, 1950-80,* December 8, 1982.

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[11] The traditional model was simplified by reducing the number of sectors from the original 18—including three exogenous energy sectors—to 12, including two endogenous energy sectors. The 12 sectors include transportation and communications, construction, services (less housing), housing, agriculture, domestic trade and other sectors, and six industrial branches—machine building, chemicals, fuels, electric power, consumer goods (including light industry and food processing), and industrial materials (including ferrous and nonferrous metals, forest products, construction materials, and other branches of industry).

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[12] A minor contribution to GNP by military personnel is also included.

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supply-side model. On the demand side, GNP is allocated among four primary end uses—investment, consumption, military spending, and government administration.

The Production Functions

At the heart of the model are 12 production functions used to forecast net output by sector of the economy. The traditional version of SOVSIM forecasts net output using the Cobb-Douglas production function:

$$Q = e^{\alpha} K^{\beta} L^{1-\beta},$$

such that

$$0<\beta<1,$$

where

- Q = value-added output (constant prices),
- K = value of the capital stock (constant prices),
- L = labor measured in man-hours,
- α = scaling parameter,
- β = capital elasticity, and
- e = the exponential function.

The capital elasticity parameter—which is estimated using historical data—reflects returns to capital during the recent past.[13] With this function, returns to new capital will be the same as returns to old capital. Thus, the traditional model provides no direct way to simulate higher returns to new capital, an important element in Gorbachev's plan for modernization.

Modeling Embodied Technological Progress. To remedy this shortcoming, the Cobb-Douglas production function was modified to allow advancement in the production technology of new capital, or in other words, to allow for embodied technological progress (see inset). This requires distinguishing between output produced using old capital from output produced using new capital, which potentially includes technologically advanced and higher quality machinery and equipment.

[13] The capital elasticity is an estimate of the percentage change in output that results when capital is increased 1 percent, holding the labor input constant.

Embodied technological progress was incorporated into the model in two ways, depending on the sector of the economy. In the first method, the capital elasticity for new capital was set higher than that for old capital, thus making new capital more productive. The productivity of old capital was constrained to that observed in the recent past. Increasing the capital elasticity implies more than just an increase in the quality of capital—it also implies a fundamental change in the nature of the capital (such as automation). The improved production technology embodied in the new capital in turn implies a reduction in the contribution of labor relative to that of capital in the production process (that is, capital "substitutes" for labor).[14] This method was used for all sectors except electric power, services, agriculture, and housing. The resulting modified Cobb-Douglas production function is:

$$Q = \alpha(t)\,[K_o^{\beta} L_o^{1-\beta} + K_n^{\gamma} L_n^{1-\gamma}],$$

such that

$$0<\beta<\gamma<1,$$

where

- Q = value-added output (constant prices),
- K_o = capital stock of vintage before 1986 (old capital),
- K_n = capital stock after 1985 vintage (new capital),
- L_o = labor input required by old capital,
- L_n = labor available for the new capital,
- $\alpha(t)$ = intercept term and adjustment cost factor,
- β = capital elasticity for old capital,
- γ = capital elasticity for new capital.

[14] This approach seemed to be most in keeping with the spirit of "restructuring" proposed by Gorbachev. He essentially called for production of capital that would produce a higher return of output than the old Brezhnev-era capital stock. This necessitated development of a vintage capital model, defining a separate vintage in each time period for which an increase in the capital elasticity was proposed.

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The Cobb-Douglas Production Function and Technological Progress

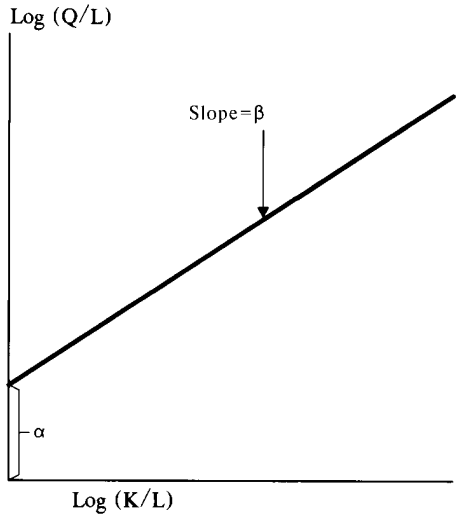
The Cobb-Douglas function has proved to be a useful empirical device for representing aggregate production functions in the context of macroeconomic modeling. The function was originally derived (by Cobb) to capture the empirical observation (by Douglas) that the wage rate was equal to the marginal product of labor. This property is desirable when the function is applied to a society with perfectly competitive markets and where production is controlled by profit-maximizing entrepreneurs, but is less appealing when applied to centrally planned economies. Other theoretical properties of the function are useful in both cases—such as constant returns to scale and diminishing marginal returns to factors—but the main justifications for using it are that it is simple, easy to estimate, and usually yields good results with highly aggregated time-series data on inputs and outputs. The Cobb-Douglas production function is expressed as:

$$Q = e^{\alpha} K^{\beta} L^{1-\beta},$$

where Q is output, K and L are capital and labor inputs, respectively, α and β are parameters, and e denotes the exponential function. α is a scaling parameter that reconciles differences in units among Q, K, and L (if Q, K, and L were index numbers, α would equal 0 and e^{α} would equal 1). β is the capital elasticity, which is a measure of the return to capital. By algebraic manipulation, the function can be transformed to its "intensive" form,

$$Log(Q/L) = \alpha + \beta log(K/L),$$

which is more useful for evaluating technological progress and for estimating the parameters.



Without modification, the Cobb-Douglas production function takes technology as given. That is, it defines how inputs are transformed to output using a defined and constant production technology. But production techniques may change over time. In a free market system, production techniques would be expected to exhibit increased technical efficiency (producing a given output with fewer inputs over time as innovations arise and competition weeds out the less efficient production technologies). This phenomenon is called technological progress, which can influence one or both of the parameters of the production function. Economists define two types of technological progress—embodied and disembodied.

Disembodied technical progress requires no change in the type of capital stock. It may, for example, be an organizational change, or represent "learning" as laborers become more familiar and adept at the production process. It is incorporated into the production function by changing the parameter α, which shifts the function shown in the figure vertically. Disembodied technological progress is frequently modeled by converting the constant α to a function of time, as follows:

$$\text{Log}(Q/L) = \alpha(t) + \beta\text{log}(K/L).$$

Embodied technological progress requires some change in the capital stock. New investment provides the major method by which this technical change is introduced. To deal with embodied technical progress, it is necessary to distinguish among vintages of capital. Technological progress through changes in capital is manifested only in the latest additions to the capital stock, whereas productivity of the old machines remains more or less constant. Embodied technological progress implies that β and possibly α must change for new capital.

This paradigm of technological progress works well for a market economy. In centrally planned economies, however, there is no invisible hand enforcing selection of the most efficient technologies—and so it is possible to move to less efficient as well as to more efficient production technologies. When movement is toward less efficient technologies, technological progress is actually negative. Thus, the term "technological change" is more appropriate when the paradigm is applied to centrally planned economies.

An important assumption implicit in the technological progress paradigm is equilibrium. Consider, for example, the steps of technological progress. The starting point is an economy well adjusted to a particular production process, operating at peak efficiency because of years of practice and learning. In other words, the economy is in equilibrium. Now introduce an innovation into the production process—something so fundamental that nearly all production processes in the economy are affected by it (for example, personal computers). What happens? The technological progress paradigm says that the production function will shift such that more output will be produced without any increase in inputs. The unstated assumption here is that this occurs only after the economy has regained equilibrium. The paradigm thus ignores the production dynamics during the adjustment period.

Adjustment costs arise from disruptions in economic activity as the economy adjusts to the new production technologies. Transformation of the technology of production in any economy—including Western economies—cannot be accomplished without these adjustment costs. The faster the pace of the transformation, the greater the adjustment costs. These adjustment costs may be especially severe in a centrally planned economy.

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The labor requirement for capital stock of vintage before 1986 was set equal to the labor demand reported in 1985, thereby providing old capital with the same labor resources it had received in the past. The remaining labor resources were made available to new capital.

The second method was to multiply the new capital input by a "productivity factor" to simulate an increase in quality without an accompanying change in the technology of production. This method was used for agriculture, services, and the electric power branch of industry, where increases in the quality of capital might occur—resulting in greater output per unit of new capital—but new, improved technologies are not expected. Again, production using old capital was constrained to productivity observed in the recent past. The function is:

$$Q = \alpha(t)\,[K_o^{\beta} L_o^{1-\beta} + (KPF \times K_n)^{\beta} L_n^{1-\beta}],$$

such that

$$0<\beta<1,$$

where

KPF = capital productivity factor.

Modeling Gains From Human Factors. The model also was modified to allow for productivity gains originating from human factors, the other major element of Gorbachev's economic strategy.[15] Human-factor effects were modeled for both old and new capital. The two production function equations presented above were modified to incorporate the human-factor multiplier (HF) as follows:

$$Q = \alpha(t)\,[K_o^{\beta} (HF \times L_o)^{1-\beta} + K_n^{\gamma} (HF \times L_n)^{1-\gamma}],$$

and

$$Q = \alpha(t)\,[K_o^{\beta} (HF \times L_o)^{1-\beta} + (KPF \times K_n)^{\beta} (HF \times L_n)^{1-\beta}].$$

The human-factor effects modeled by HF are those that result from the regime's efforts to institute better management and planning, the discipline and anti-alcoholism campaigns, and improved labor incentives—policies that act to increase the productive utility of labor (for example, factors that make the real labor effort more intensive while the nominal measure of labor remains unchanged).[16] Human-factor effects do not include recorded increases in the number of hours worked or the increased number of workers. (They do, however, represent increases in hours worked when they are not reflected in the official Soviet statistics.) For example, setting HF=1.10 implies that the productive utility—or efficiency—of existing labor resources will be 10 percent greater than the average productive utility observed during the recent past. In simple terms, labor will "work 10 percent harder."

Production Functions for Agriculture and Housing. The production function for agriculture differed from this general form in two ways; weather was included in the function, and the labor input was not disaggregated and allocated according to the capital vintage. Weather effects were modeled by expanding the intercept term—$\alpha(t)$—to include relevant weather variables. Labor was not disaggregated as done for other sectors because labor in agriculture is much more fungible than in other sectors, making it impractical to allocate a portion of the agricultural labor force exclusively to new capital. Gains in productivity from higher quality farm machinery and equipment were incorporated into the capital productivity factor (KPF) for new capital. The resulting production function for agriculture is:

$$Q = \alpha_1 (W, t)\, e^{\alpha} (KPF \times K_n + K_o)^{\beta} (HF \times L)^{1-\beta},$$

where $\alpha_1(W,t)$ is the adjustment function for weather.[17]

[15] With the traditional model, average productivity for the recent past was embodied in projections, but it was not possible to simulate additional human-factor effects.

[16] According to Abel Aganbegyan, writing in the Soviet labor newspaper *Trud* in 1981, one-half of the decline in growth of labor productivity that occurred in 1976-80 compared with 1971-75 was because of "people's attitudes toward their work." Andropov recovered some of the earlier momentum with the initiation of a tough discipline campaign in 1982; labor productivity rose by 3.2 percent in industry in 1983, in part because slackers were forced to actually be on the job during the time they were counted as being there. Gorbachev's labor force initiatives, together with his direct appeal to workers, may elicit a greater effort by many who might otherwise merely put in their time.

[17] The production function for agriculture estimates net agricultural output, which excludes intra-agricultural use of farm products but does not make an adjustment for purchases by agriculture from other sectors. Net agricultural output was converted to value-added units by subtracting intersectoral inputs before making the calculation of agriculture's contribution to GNP.

25X1

The function used for housing includes only capital as an input, as follows:

$$Q = e^{\alpha} K^{\beta}.$$

Basically, this function calculates the conversion of housing measured in capital stock units (1973 rubles) to housing measured in constant (factor-cost) rubles. Because it does not represent a legitimate production relationship, features for modernization were not incorporated into the function.

Modeling Adjustment Costs. Changes in the production technologies of an economy cannot be accomplished without adjustment costs, and the faster the pace of the transformation, the greater these costs will be. Soviet history provides examples of such costs of abrupt shifts in policies and resource allocations.

In the latter half of the 1950s and early 1960s, Nikita Khrushchev pushed through major changes on a broad front—the "Virgin Lands" and other campaigns in agriculture, a crash program to develop the chemical industry, a sharp change in the composition of military production, and major reorganizations of the administrative bureaucracy. At the same time there was a drastic change in investment policy—the growth rate for investment of fixed assets fell from 13 to 14 percent during 1954-58 to less than 7 percent in 1958-63.[18] As it turned out, the substantial expansion of cultivated land (especially for corn) had little payoff in the long run. The crash program in the chemical industries—based largely on imported plant and equipment—produced a good deal of waste and deprived other industries of vital investment funds. The shift to a regionally based system for managing the industrial and construction sectors thoroughly fouled up the flow of supplies to enterprises, and frequent reorganizations created discord within the bureaucracy and confusion and uncertainty for enterprises. Partly as a consequence of trying to change too much too fast, Soviet GNP growth fell from 7.0 percent per year during 1954-58, when Khrushchev was at his pinnacle, to 3.7 percent per year during 1959-63. In 1964 Khrushchev was removed from power.

[18] See Herbert Block, "Soviet Economic Power Growth—Achievements Under Handicaps," in Joint Economic Committee, US Congress, *Soviet Economy in a New Perspective*, 1976, pp. 243-268.

A second example of a growth slowdown as a result of sudden changes in government policies—especially investment plans—occurred during Brezhnev's rule in the late 1970s and early 1980s (see inset). 25X1

Like Khrushchev, Gorbachev is pushing for change on many fronts simultaneously, but with even more force and speed. Despite his expectations to the contrary, Gorbachev's modernization drive can also be expected to result in production setbacks in the short run as the economy adjusts: 25X1

- The State Acceptance Program to improve the quality of products has initially disrupted production and the supply network as poor-quality goods are rejected.
- The wage reform is already meeting resistance, especially by those who are hurt by it.
- The self-financing initiative in industry, if vigorously implemented, will create uncertainty and could disrupt existing supply-demand mechanisms. 25X1 25X1

But perhaps the most disruptive element of Gorbachev's program is the sudden reallocation of investment priorities to the production of machinery, putting other important sectors on short rations. Already there is evidence that the planned increase in investment is too great to absorb effectively. In 1986 the actual growth rate of investment in civilian machine building was 17 percent, compared with the planned rate of 30 percent, and there were complaints about the quality of new equipment. 25X1

To model these expected adjustment costs, the intercept term was expanded to a function of time—$\alpha(t)$— 25X1 to permit downward shifts in the production function during the transition period, as follows:

$\alpha(t) = e^{(\alpha \text{ - adjustment cost factor for each year})}$ 25X1

25X1

Forecasting Labor

A projection of the Soviet work force to the year 2000 has been made by the Center for International Research (CIR). In the model, this expected increase in total employment is allocated among sectors of the

Causes of the Great Industrial Slowdown, 1976-82: A Lesson From History

From 1976 to 1978, all the major branches of Soviet industry experienced a sharp reduction in output growth. The economic slump persisted through 1982, and complete recovery has not yet occurred. The drop was precipitated by a decision to cut sharply the planned growth rate for industrial output in 1976 and, simultaneously, to reduce the growth of new fixed investment. [a] *Indeed, achieved growth rates of output and investment dropped abruptly in 1976, but the upsurge in growth and productivity that was planned for the following years never came.*

The planned recovery never materialized because the planners had given the production system a shock from which it never recovered and set in motion processes in the sphere of investment that proved seriously adverse. Specifically, the emphasis on renovating enterprises produced an investment mix that neither added proportionately to new capacity nor replaced much old technology with efficient new varieties. The situation was exacerbated by a sudden change in plans in 1978 to reallocate a substantial amount of industrial investment to develop oil and gas resources in West Siberia. In devising and implementing their new growth strategy—which was intended to yield a decisive increase in the efficiency of resource use and improvement in the quality of products—the planners overlooked the severity of three looming constraints, which were the result of years of investment neglect and inattention to long-range planning.

The first, and possibly the most critical, constraint was in the supply of several basic raw materials and intermediates—iron ore, coal, steel, lumber, and nonmetallic minerals. Widespread shortages of these products began to occur, largely as a consequence of years of heavy investment in industries that require these inputs, and the relative neglect of investment in industries that supply them. Shortages of extractive raw materials, along with a deterioration in quality, began to limit output first in steel, lumber, and construction materials, and then in the processing industries themselves—chemicals, machinery, and paper.

The second constraint was in energy. Despite many years of debate about the need for a better, long-term energy strategy, the planners apparently did not correctly gauge the speed with which this constraint was developing or appreciate how costly it would be to alleviate. Only when fuel shortages began to plague the industrial sector did planners respond, implementing conservation campaigns (primarily through rationing) and the crash program in West Siberia. Shortages of coal—which serves as a raw material and as fuel—were particularly serious, contributing to a near collapse in the growth of rolled steel products and leading to power outages, brownouts, and an erosion in the quality of electric power.

Bottlenecks in rail transportation proved to be a third serious constraint on industrial growth and efficiency. Despite warnings from specialists, planners ignored the fact that railroads were strained to the verge of breakdown, the legacy of years of investment neglect and unwise investment allocations. Frequent failure of the railroads to meet shipment schedules led to

25X1

intermittent plant shutdowns, production-line disruptions, and idle machines and workers. The railroads had reached the limit of their capacity to move ever more freight with their existing lines and technology.

Other developments added to the troubles of the already suffering industrial sector. Planners continued to give high priority to military production, and the situation was made worse by unexpected demands arising from the invasion of Afghanistan and the large-scale army maneuvers in response to the events in Poland. Rigidities in the conduct of foreign trade hampered the use of trade to alleviate shortages. And finally, enterprise managers were burdened as never before by the need to deal somehow with frequent changes in the rules governing incentives, campaigns to conserve on everything at once, orders to join one or another large-scale economic experiment, pressure to form new organizational arrangements, and escalating demands to produce more consumer goods.

In summary, the 1976-82 industrial growth slowdown was precipitated by the planners, whose intention was to reinvigorate industrial production and accelerate productivity gains. The disruptions caused by their efforts to change the system were intensified by the three lurking constraints that the Soviet Union still faces today. The lesson from this is clear—abrupt changes in the production processes of a centrally planned economy like that of the Soviet Union, where there are no automatic mechanisms to bring supply into balance with demand, are very costly and carry with them the very real risk of making things worse, even though the intent is to improve the system.

economy according to investment priorities and the historical relationship between investment allocations and the employment increment:

$$L = L_{-1} + \lambda_1 \lambda_2 \Delta M$$

where

- L = labor in man-hours allocated to a particular sector,
- ΔM = the increment of new workers entering the civilian economy,
- λ_1 = parameter converting number of workers to man-hours, and
- λ_2 = share of new workers allocated to a particular sector as a function of the capital investment share, determined by multiplying the investment share by the historical ratio of the share of new workers to the investment share during the recent past (1981-85).

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Within each sector, labor required by old capital (L_o) is set by multiplying the amount of old capital by the inverse of the capital-labor ratio in 1985. Additional labor from increases in the overall labor supply (ΔM) and from labor displaced by retirement of old capital is allocated to new capital. Equations for L_n and L_o are:

$$L_o = \omega K_o \text{ and } L_n = L - L_o,$$

where ω is the inverse of the 1985 capital-labor ratio.

25X1

This is a more realistic way to model the Soviet economy than was the case with the traditional model, which assumed labor was completely malleable. As new capital was added in the traditional model, suitable labor was automatically available. In the revised model, new labor originates from either new entrants into the labor pool, or from workers displaced by the retirement of old capital.

25X1

25X1

Forecasting Capital

Values for new capital are generated in the revised model by accumulating commissionings beginning in 1986.[19] Future values for old capital are generated by subtracting retirements from the value of the old capital stock from the previous period. The equations are:

$$K_n = K_{n-1} + C,$$
$$K_o = K_{o-1} - R,$$

where

K = value of capital stock at the end of the year,
R = retirements of capital stock, and
C = commissionings.

Retirements are calculated by multiplying the total capital stock at the beginning of the year by the planned retirement rate. Commissionings are generated from new fixed investment, which in turn is generated by output from the machine-building and construction sectors.[20] Total new fixed investment is distributed among sectors of the economy exogenously, typically according to published Soviet plans.

Measuring the Return to Capital

Whereas the production functions are the heart of the model, the capital elasticities—the model's measure of the return to capital in each sector—are the heart of the production functions. To project GNP growth, estimates are needed of the capital elasticities. Estimates for old capital are made on the basis of the historical relationship between inputs and output. These estimates are appropriate, since they represent actual productivity measurements on existing capital stock, which will still be producing output in future years. To model technological change, however, we also need to estimate how much the capital elasticities might increase as a result of Gorbachev's modernization program, as well as the extent and duration of the adjustment period. The historical record is less useful for this latter objective, but important insights can be obtained, nonetheless. 25X1

A Graphical Approach 25X1

The intensive form of the Cobb-Douglas production function,

$$\text{Log}(Q/L) = \alpha + \beta \log(K/L),$$

suggests that β—the capital elasticity—can be "observed" by plotting log(Q/L) versus log(K/L). In the case with no technological change, the slope of the curve is β. If the historical data conform closely to the Cobb-Douglas production function, the data will form a reasonably straight line, as shown in figure 3a. The data will never form a completely straight line because of perturbations owing to factors other than K and L that affect output but are not included explicitly in the production function (such as weather). 25X1

Technological progress or change will alter this idealized pattern. Assume, for example, that disembodied technological progress occurred at a fairly steady rate per year. This would shift the intercept upward the same amount each year, as shown in figure 3b. 25X1
Alternatively, embodied technological change can affect both the intercept and the slope of the line, as shown in figure 3c. It is impossible to determine from the plot alone the extent of technological progress or its form (embodied versus disembodied). Even if the

25X1

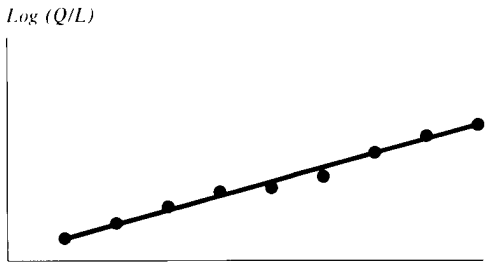
[19] Commissionings are gross additions to capital, including: the value of new enterprises, buildings, and installations completed and put into service; the value of all types of equipment put into service; the value of additional production tools; the value of additions to perennial plantings; the cost of work to irrigate and drain land; and other outlays augmenting the value of fixed assets.

[20] Commissionings are generated as a weighted average of new fixed investment for the current year and for up to three previous years. Total new fixed investment is calculated by adding machinery imports to the output from the machine building and construction sectors, and subtracting the amount of machinery, equipment, buildings and structures allocated for export, capital repair, consumer durables, and military procurement. Capital repair is estimated using an equation that relates previous capital repair costs to the size of the capital stock. Other end uses for machinery, equipment, buildings, and structures are set exogenously.

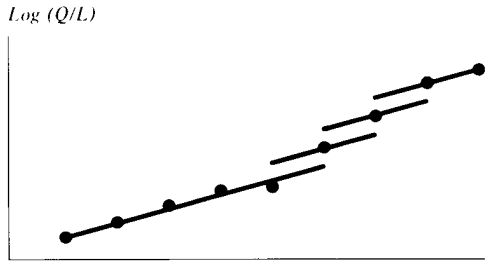
Figure 3
Modeling Technological Progress

Q = Output
L = Labor
K = Capital

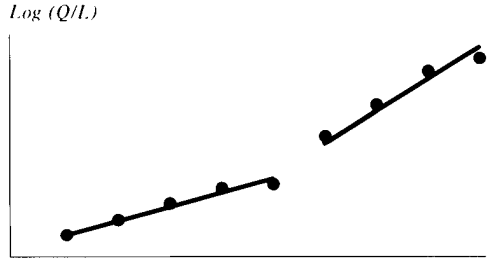
3a. No Technological Progress



3b. Disembodied Technological Progress



3c. Embodied Technological Progress



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plot exhibits a nearly straight line, it is not clear that it did not originate simply by a regular annual shift in the intercept.[21]

25X1

To estimate $\alpha(t)$ and β, it is necessary to separate movements along the curve from vertical shifts of the curve. This is technically not possible without a great deal of additional information, which is not available. Nonetheless, estimates of $\alpha(t)$ and β can be obtained by imposing two simplifying assumptions. The first assumption is that there exists a constant capital elasticity for each sector over the last 10 or more years. The second assumption is that any technological change (both positive and negative) that may have occurred is of the disembodied form and will be evidenced by shifts in the intercept. These assumptions are consistent with the observation that technological change has been very slow in the USSR. With these two assumptions, the task of divining estimates of α and β reduces to a problem of finding a straight line with the right slope such that it will come close to each point when the intercept is shifted in a reasonable manner.

25X1

This graphical approach is applied to each of the economic sectors in the following section. The results of the graphical analyses are then used in conjunction with standard statistical procedures to estimate $\alpha(t)$ and β.

25X1

[21] Problems in measuring the historical capital and labor series can also obfuscate the production relationship. For example, labor measured in total hours spent at the job site would overstate the labor input during slack periods when workers showed up for work but had little or nothing to do (caused, for example, by supply bottlenecks or equipment failure). Similarly, capital measured in rubles and not adjusted for inflation would overstate the actual capital that contributed to production of output. Another case of mismeasurement would occur if capital was not adjusted for excess (unused) capacity, or for downtime owing to shortages of some other input (for example, raw materials or energy). In all of these cases, the curve would shift downward for the years in which labor and capital were overstated.

An additional complication arises for extractive resources (for example, fuels and some raw materials). Because these resources become more costly to produce as the reserves become depleted, the plot would be expected to exhibit signs of diminishing marginal returns—or increasing extraction costs—as more and more capital is required each year just to maintain production. In our plot, this would be manifested as a change in the slope of the curve over time.

25X1

25X1

Application of the Approach to Each Sector of the Economy

Transportation and Communications. To apply the graphical approach outlined above to the transportation and communications sector, the logarithm of the output-labor ratio is plotted against the logarithm of the capital-labor ratio for the last 17 years for which data are available (1969-85) in figure 10a (in back of paper). It is readily apparent that the slope of the curve fell after 1976, suggesting that the return to capital had decreased. A plausible explanation for the change in slope is that, at about this time, the railroads had reached the limit of their capacity to move freight on the existing network with existing technology.[22] The continued attempts to push the intensity of use even further clogged the system's arteries, rendering it accident prone, and severely reduced its efficiency. Bottlenecks in the rail transport of both raw materials and finished products—especially coal, lumber, ores, machinery, and petroleum products—constitute one of the primary causes of the industrial slowdown in the late 1970s and early 1980s (see inset).

The slope of the curve for 1977-85 was used as an estimate of the return to existing capital (β), and the associated intercept was used as an estimate of $\alpha(t)$, that is, $\alpha(t)$ in this case reduces to a simple constant, e^{α}. Use of these estimates implicitly assumes that capacity constraints in the transportation sector will not worsen in the future. A return to the higher slope of the 1960s and early 1970s is only possible if the railway network is greatly expanded (for example, more track), which at present is not included in Soviet plans.[23]

Industry. A similar though much more pronounced pattern was observed for the *fuels* sector (see figure 10b). A sharp break in the slope of the curve occurred after 1977, suggesting a sudden drop in the return to capital. An upward jump in the intercept seems to have occurred during 1983, but otherwise the return to capital remained at about zero through 1985. In other words, nearly all additions to inputs were required to simply maintain fuels production since 1977. Because fuels comprise extractive resources (oil, coal, gas), this pattern is reasonable. As resources are depleted, output is maintained only by exploiting reserves that are of lower quality or are more costly to extract (in terms of real opportunity costs of the labor and capital inputs). Shortages of fuel, which began to appear in 1976-77, constitute another of the primary causes of the industrial slowdown in the late 1970s and early 1980s. Because it is not anticipated that the return to capital in the fuels sector will improve, the slope of the curve for 1978-85 was used as an estimate of the return to existing capital (β), and the associated intercept was used as an estimate of $\alpha(t)$, that is, $\alpha(t)=e^{\alpha}$. 25X1

The pattern observed in the plots for the remaining industrial sectors differed from that observed for fuels. In general, bottlenecks caused by troubles in the transportation sector and shortages of fuels and other basic raw materials depressed industrial growth during 1976-82. Apparently, the effects of these bottlenecks—and the planning mistakes they led to—worsened each year until about 1982.[24] After 1982, the slopes of the curves seemed to return to pre-1976 levels. However, there was no indication that the intercept shifted upward to previous levels, suggesting that supply bottlenecks and their effects did not improve after 1982 but merely ceased to get worse.[25] 25X1 25X1 25X1

[23] The amount of railway expansion required could only be accomplished with an enormous increase in investment, which would preclude much of the capital modernization drive. 25X1

[24] It is also possible that the additional capital commissioned during this time was basically unusable, or was grossly overvalued. 25X1

[25] Another explanation, however, may be that the attempts to change the production process resulted in disruptive changes that actually moved industry to less efficient production technologies. One way this could happen is if the product mix demanded (by planners) was altered to account for the increasing scarcity of raw materials, so that industry was forced to try to make do and produce the new products with machinery and equipment that were not efficient at producing them. Many aspects of the production process must change when the product mix changes; if all of the changes are not made, inefficiency results. 25X1 25X1 25X1

The plot for the chemical sector is shown in figure 10c. A nearly straight line can be drawn through the points for 1969-77. A second straight line with about the same slope can be drawn through points for 1982-85. This strongly suggests that the underlying β is approximately equal to the common slope of these two lines. But during 1978-82 there was almost no return to additions to capital. Under our assumptions, a temporary drop in β (to nearly zero, in this case) is not allowed. Therefore, it is postulated that the function shifted downward each of those years (negative technological change), as a result of the industrywide economic disruptions that occurred during this time. Then, in 1983, the downward slump was arrested, and production continued along the previous trend.

Similar reasoning can be used to evaluate plots for industrial materials, consumer goods, and electric power (see figures 10d, e, and f).[26] In each of these sectors, a similar slump was observed during the 1976-82 period, followed by a return to the pre-1976 trend. The growth slowdown in industrial materials is another of the major causes often given for the problems in the late 1970s and early 1980s. For example, shortages of iron ore, coking coal, and scrap metal contributed in a major way to the near stagnation in steel production. Shortages of steel, in turn, limited growth of construction and machinery production—which are the sources of investment—and may also have contributed to a slowed growth of military production. Declining growth in coal production and its deteriorating quality were especially hard on production of electric power and metallurgy. Shortages of electricity led to more frequent power outages and a growing share of power supplied at below-standard frequency and voltage, often causing serious equipment losses—effects that exacerbated the basic problem of resource scarcity.

Trends in the plot for machine building are less clear, but seem to follow the same pattern as described for the previous four industrial sectors. A common slope was detected for the years 1969-70, 1973-76, and 1983-85 (see figure 10g). There appeared to be a slump in 1971-72, followed by a complete recovery in 1973. The growth slowdown period is assumed to extend from 1977 to 1983. 25X1

The slopes of the curves for years excluding the slump period were used as estimates of the return to existing capital (β) for the five industrial sectors, excluding fuels. The function $\alpha(t)$ was estimated by adding to the intercept term a time-dependent term that measured the average annual downward shift in the intercept during the slump period. Estimating $\alpha(t)$ in this way permits the simulation of the effects of similar disruptions in economic activity in future years. 25X1 25X1

Construction. The plot for construction is interesting in that there appears to have been a complete recovery from the slump of the late 1970s (see figure 10h). A straight line can be drawn through points for the years 1972-75 and 1981-85. It appears that the curve shifted downward in 1976-77, continued along the trend until 1979, and then shifted upward to its previous position by 1981. A growth slowdown of this nature could be explained by short-term disruptions of economic activity, such as the material bottlenecks that occurred during this time. The apparent recovery could be explained by the elimination of the bottlenecks and the return to use of the excess capacity created by the bottlenecks. A similar phenomenon was observed in agriculture during 1979-83. 25X1

The slope of the curve for 1971-85, after accounting for the intercept shifts in 1976-77 and 1980, was used as an estimate of the return to existing capital (β). The function $\alpha(t)$ was estimated by adding to the intercept term an additional term estimating the magnitude of the downward shift in 1976. 25X1 25X1

Domestic Trade and Other Sectors, Services, and Housing. Interpretation of the plots for these three sectors is straightforward (see figures 10i, j, and k). A single straight line can be drawn through all the

[26] Changes in investment policies by the Soviet Government are also apparent in these plots. Because the capital-labor ratio has increased each year, the points are ordered chronologically from left to right. Points that are close together indicate low capital growth, while points spaced widely apart indicate high capital growth. The switch to lower investment growth after 1976 is apparent in the figures for the industrial sectors. 25X1

points in domestic trade and other sectors starting in 1972. For services (excluding housing), a straight line can be drawn through points since 1977. Similarly, a straight line can be drawn through the points for housing. The slopes of these curves were used to estimate the return to capital, and the associated intercept was used to estimate $\alpha(t)$, that is, $\alpha(t)=e^{\alpha}$. 25X1

There is no evidence of any impact on production in these sectors because of the industrial growth slowdown in 1976-82. Therefore, it was assumed that any economic disruptions caused by Gorbachev's policy changes would have little or no impact on domestic trade, services, and housing in future years. 25X1

Agriculture. The production function for agriculture is documented in a separate report.[27] The graphical approach applied to the other sectors is not suitable for agriculture because of the pronounced effects of weather. The industrial slowdown had a significant impact on agricultural production, causing shortages and delayed deliveries of inputs from other sectors, such as feed additives, energy, and agrochemicals. A growth slump unrelated to the weather occurred during 1979-83, followed by an apparent recovery. The intercept function, $\alpha_i(W,t)$, includes a term that estimates the magnitude of the downward shift in 1979 for use in simulating the effects of future disruptions in economic activity. 25X1

Statistical Estimates of Production Function Parameters

Following from the rationale presented in the previous section, β was estimated for each of the sectors using multiple regression. The function $\alpha(t)$ was estimated for the seven sectors that exhibited a growth slowdown during 1976-82—industrial materials, machine building, chemicals, consumer goods, electric power, construction, and agriculture. Because the remaining sectors—transportation and communications, domestic trade and other sectors, housing, fuels, and services—did not exhibit any shifts in the production function during this time, estimates of a constant intercept were made. Data for 1969-85 were used to fit production functions for all but two sectors—services and domestic trade and other sectors, which were fitted using data for 1972-85. Four different models were used to accommodate the various options. 25X1

Model 1. The model used to estimate parameters for the transportation and communications sector and for the fuels sector was: 25X1

$$\text{Log}(Q/L) = \alpha + \beta \log(K/L) + A_2 \times \text{DUM} + A_3 \times \log(K/L) \times \text{DUM}$$

where DUM represents a dummy variable for years before 1978 for fuels and before 1977 for transportation and communications.[28] The change in slope observed coincident with the beginning of the growth slowdown period was modeled by the interaction term between log(K/L) and DUM. The model for the fuels sector included an additional dummy variable for the years 1978-82. 25X1 25X1

Model 2. For the industrial sectors other than fuels, the following model was used:

$$\text{Log}(Q/L) = A_0 + A_1 \times \text{DUM} \times t + \beta \log(K/L) + A_2 \times \text{DUM1},$$

where DUM represents the growth slowdown period (which varied by sector, but was during 1976-82), t is time with t=1 corresponding to the first year of the growth slump, and DUM1 is a dummy variable for the years 1982-85, when the annual downward shift in the intercept appeared to have been arrested. An additional dummy variable was included for machine building for 1971-72. 25X1 25X1

The coefficient A_1 is a measure of the annual downward shift in the intercept during the growth slowdown period. For these sectors,

$$\alpha(t) = e^{(A_0 + A_1 \times \text{SLUMP} + A_2)},$$

where $A_0 + A_2 = \alpha$ and SLUMP is a variable used in the model to simulate intensity of economic disruption. 25X1

[28] A dummy variable is a time-series sequence of 1's and 0's. Here, DUM was set equal to 0 for recent years and 1 for years before 1977-78. 25X1 25X1

Model 3. The model used for the construction sector was:

$$\text{Log}(Q/L) = A_0 + \beta \log(K/L) + A_1 \times \text{DUM1} + A_2 \times \text{DUM2} + A_3 \times \text{DUM3},$$

where DUM1 is a dummy variable for 1976 and 1980 (taking the value of 1 for those two years and 0 for all other years), DUM2 is a dummy variable for 1977-79, and DUM3 is a dummy variable for 1969-71. The function $\alpha(t)$ is estimated by $e^{(A_0 + A_1 * \text{SLUMP})}$, where $A_0 = \alpha$.

Model 4. For domestic trade and other sectors, services, and housing, both β and α—which are constant in these sectors—were estimated directly:

$$\text{Log}(Q/L) = \alpha + \beta \log(K/L).$$

Two dummy variables were added to the model for services, one for 1972-75 and one for 1976. The function for housing did not include labor as an input.

The range of capital elasticities obtained using these models is striking (see table 1).[29] The highest was 0.89, which occurred for electric power. The elasticity for chemicals—0.73—was also quite high. The lowest elasticity was measured for fuels—0.04. Low elasticities were also measured for domestic trade and other sectors, services, and agriculture, all of which were less than 0.2. The elasticities for the remaining industrial sectors were all about 0.4 to 0.5.

[29] Statistical properties of these models and the data used to estimate the parameters are presented in appendix A. In all cases the data fit the models well. $\bar{R}^2$ s exceeded 0.98 and exceeded 0.995 for several sectors. In addition, the estimated functions predicted 1986 output quite closely. Predicted values for 1986 were obtained by solving the estimated production functions using values of capital and labor estimated by the macroeconomic model. Except for transportation and communications, construction, and agriculture, predictions were within 700,000 rubles. Construction output was underestimated by 1.4 billion rubles, and transportation and communications output was underestimated by 1.1 billion rubles. The prediction for net agriculture was low by about 5 billion rubles.

Production functions were adjusted for this "error" by creating addfactors for each function that took the value of the discrepancy between the predicted and observed figures for 1986. As a result, the predicted value of GNP for 1986 corresponded exactly to the observed value. In the case of agriculture, this procedure may result in an overestimate of future production because it is unlikely that the factors that led to the discrepancy in 1986 will be repeated every year.

Simulating Future Economic Performance

Returns to Capital and Human Factors in the Context of the 1986-90 Five-Year Plan

Whereas statistical estimates can be made of the return to existing capital and labor, as was done in the previous section, returns to new capital and human factors in the future depend on the extent to which Gorbachev's revitalization initiatives are successful. If his program were implemented superficially, resulting in no improvement in work effort and no appreciable technological progress, then no additional human factor effects would be expected, nor would it be likely that the returns to new capital would be any greater than the returns to existing capital. If Gorbachev's program were completely successful, on the other hand, the Soviets would fulfill the plan goals for the 1986-90 Five-Year Plan. Neither of these extreme cases is very likely, but they give us some indication of the bounds on the returns to capital and labor.

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The macroeconomic model outlined above was used to determine the gains from capital modernization and from human-factor effects required to meet the implied nonagricultural GNP growth goal in the current five-year plan—4.1 percent per year.[30] A reference point for the analysis was created by defining a baseline scenario that incorporates investment shares and capital retirement rates planned for 1986-90, but assumes no increases above the 1981-85 average in production technology for new capital or productivity gains originating from human factors. In terms of the

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[30] Calculation of the required increase in γ or KPF and HF excluded the agricultural sector because Gorbachev's program focuses so heavily on the industrial sector that it is not likely that similar gains would occur in agriculture during 1986-90. The 1986 growth rate for nonagricultural GNP was 3.2 percent

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which is substantial improvement over the 2.1-percent average for 1981-85, but is still far short of the required average annual growth rate if the 1986-90 plan is to be met.

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Table 1
Production Function Parameters

	Scaling Factor (α)	Capital Elasticity (β)	Slump Parameter (A_i)	$\overline{R}^2$	Output in 1986 *(billion rubles)*	
					Predicted	Observed
Industrial materials	.297613	.454937	−.026580	.987	70.71	70.06
Machine building	.128875	.523432	−.027334	.991	87.84	87.96
Chemicals	−.384510	.727752	−.050993	.993	23.06	22.76
Consumer goods	.297141	.422763	−.007543	.996	41.60	41.00
Fuels	2.156876	.039291		.999	26.22	26.77
Electric power	−1.104020	.891543	−.015004	.997	23.41	23.02
Construction	.716375	.285576	−.022500	.998	62.30	63.72
Transportation and communications	.502982	.329566		.997	90.42	91.56
Domestic trade and other sectors	.683270	.175383		.984	55.27	55.58
Services	.334064	.197748		.996	105.22	105.93
Housing	.688387	.478880		.999	36.72	36.88
Net agriculture [a]	. . . [b]	.162360	−.057260	.953	130.10	135.33

Note: The general form of the production function is:

$$Q = \alpha(t)\, K^{\beta} L^{1-\beta},$$

where

$$\alpha(t) = e^{\alpha + A_i} \times \text{SLUMP},$$

and SLUMP defines the intensity and duration of the economic stagnation.
[a] The production function for agriculture estimates net agriculture, which is the sum of the value of total crop production (less seed and waste) and the net value of livestock production (including inventory, excluding feed). In the model, an adjustment is made to account for purchases by agriculture from other sectors of the economy before GNP is calculated.
[b] The intercept term is a function of weather.

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model, γ was set equal to β, and HF (human-factor multiplier) and KPF (capital productivity factor) were set equal to 1 (see inset). Estimates of β were those presented in the preceding section, and $\alpha(t)$ was estimated with the variable SLUMP equal to zero, thus precluding the possibility of production losses owing to economic disruptions. Other assumptions used in projecting the baseline were made by simply extending the trends for recent years (usually 1981-85) into the future. (A complete list of assumptions associated with the baseline scenario is presented in appendix B.) This reference point thus simulates what the economy would be like during the current five-year plan period without any benefit from Gorbachev's economic revitalization program. Under these conditions, the model predicts that the average annual growth in nonagricultural GNP for 1986-90—incorporating actual results for 1986—would be 2.3 percent.

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Recalling the Model

The production function equations:

$$Q = \alpha(t)[K_o^{\beta}(HF \times L_o)^{1-\beta} + Kn_1^{\gamma}(HF \times Ln_1)^{1-\gamma}],$$

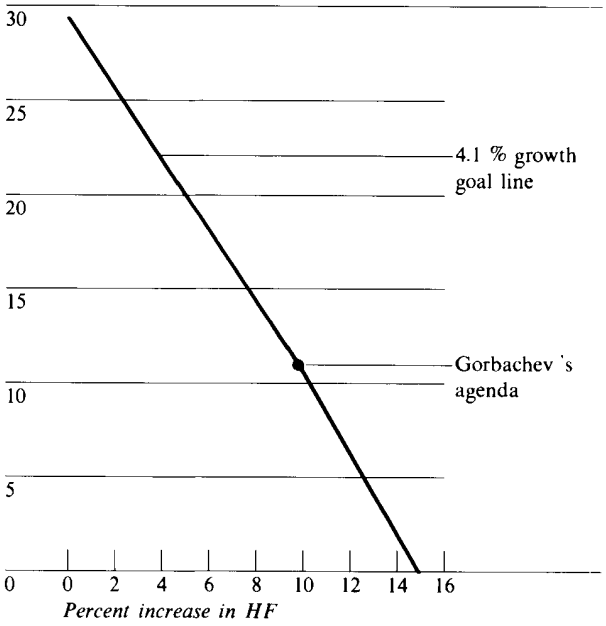
and

$$Q = \alpha(t)[K_o^{\beta}(HF \times L_o)^{1-\beta} + (KPF_1 \times Kn_1)^{\beta}(HF \times Ln_1)^{1-\beta}],$$

where

- Q = value-added output (constant prices),
- K_o = capital stock of vintage before 1986 ("old" capital),
- Kn_1 = capital stock of 1986-90 vintage,
- L_o = labor input required by "old" capital,
- Ln_1 = labor available for the 1986-90 vintage capital,
- $\alpha(t)$ = intercept term and adjustment cost factor,
- β = capital elasticity for "old" capital,
- γ = capital elasticity for 1986-90 vintage capital,
- HF = Human-factor multiplier, and
- KPF_1 = capital productivity factor for 1986-90 vintage capital.

Figure 4
Increase in Modernization Parameters (γ or KPF and HF) Required To Achieve 4.1-Percent Annual Growth in Output [a]



[a] Excluding agriculture.

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The gains from capital modernization and human factors required to bring growth up to the 4.1-percent goal were determined by repeating the baseline scenario after increasing γ or KPF and HF. The goal is attainable with capital modernization gains alone when γ or KPF for all sectors was increased 29 percent above the pre-1986 level. To reach the same goal through human factors alone would require an increase in HF for all sectors of 15 percent above pre-1986 levels. These kinds of modernization gains are unprecedented and seem impossible to achieve by 1990.

A combination of human-factor effects and technological progress is more reasonable and probably best reflects Gorbachev's strategy. Combinations of γ or KPF and HF required to meet the GNP growth goal of 4.1 percent per year are shown in figure 4. The combination labeled "Gorbachev's agenda" corresponds to the following statement by Ryzhkov: "The scale of assimilation of new machinery and technology planned for the Five-Year Plan as a whole will account for more than two-thirds of the increase in the productivity of social labor."[31]

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[31] Report by N. I. Ryzhkov, Chairman of the USSR Council of Ministers, "On the Basic Guidelines for the Economic and Social Development of the USSR for the years 1986-1990 and the Period Through the Year 2000," delivered 3 March 1986 at the 27th Party Congress.

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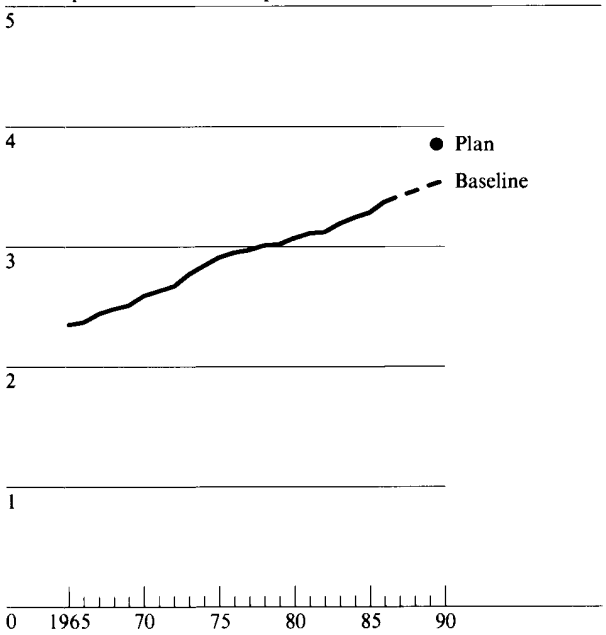
Figure 5
Labor Productivity [a]



[a] Labor productivity is the ratio of output to labor. Output is factor cost (less agriculture) in billions of rubles (1982 prices). Labor is billions of man-hours.

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HF would have to increase 9.8 percent above pre-1986 trends and γ or KPF would have to increase 11.0 percent to meet this condition:[32]

	γ or KPF	HF
Capital modernization alone	29.4%	0%
Human factors alone	0%	14.9%
Combination	11.0%	9.8%

[32] Increasing γ or KPF by 11.0 percent (with no increase in HF) results in 2.2-percent average annual growth in labor productivity, which is about two-thirds of the rate required to meet the output growth goal of 4.1 percent. With γ and KPF set at 11.0 percent, HF must equal 9.8 percent for GNP growth to equal the 4.1-percent goal.

In terms of labor productivity, the annual growth rate would have to be 3.3 percent to meet the GNP growth goal, which is three times greater than the 1981-85 average of 1.1 percent per year (see figure 5). Gorbachev's program would have to work exceedingly well to increase γ or KPF and HF this much.

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Simulating Performance to the Year 2000

The model was used to evaluate economic prospects of Gorbachev's revitalization program for the current five-year plan and for the 1990s. There is, however, considerable uncertainty in projecting Soviet economic growth to the year 2000. First, the extent to which Gorbachev's programs will be implemented is unknown, and, if implemented, the achievement of measurable advances in technological progress is uncertain. In addition, uncertainty about future values of "exogenous" variables—such as the price of oil and volume of trade with the West—grows large as the projection period extends beyond about five years. Furthermore, we have little information about Soviet plans in the 1990s—such as plans for investment growth, investment allocation, and capital retirement rates. Although sufficient information is not available to make a precise projection, alternative scenarios can be simulated to provide insights about what is possible.

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Three scenarios were developed. The first scenario portrays a future wherein the trends of the recent past extend into the future without change, thus disallowing gains from capital modernization or human factors. The last two scenarios project growth under the assumption that Gorbachev's program is vigorously implemented during the next four to five years, causing changes in longstanding economic mechanisms and practices that prove disruptive in the short run.[33] The difference between these latter two scenarios is determined by whether Gorbachev's program

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[33] In his 26 June 1987 plenum speech, Gorbachev acknowledged there had already been some disruption resulting from "restructuring" when he said: "In the first months of the year grave errors were committed which led to disruptions in many areas of the economy. Both the Politburo and the government had to take urgent measures to rectify the situation. Even though the situation is returning to normal, considerable damage has nevertheless been done."

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Quality Versus Quantity

Our projection of GNP growth does not account for quality changes, although some of the quality improvement that would be expected in the "Gorbachev wins" scenario is captured in the modernization parameters. A number of recent statements by Soviet officials indicate that the success of Gorbachev's program will be judged not only on the quantity *of production, as measured by GNP growth rates, but also on the* quality *of production:*

- *In March 1987, Soviet Politburo member Lev Zaykov, speaking to the Czechoslovak Central Committee about engineering (machinery) production said: "But growth as such is not the most important thing. The policy of the development of engineering is above all a policy of its far-reaching qualitative modernization."*
- *In April 1987, L. I. Abalkin wrote in* Mirovaya ekonomika i mezhdunarodnye otnosheniya, *No. 4: "It is entirely wrong to identify acceleration with economic growth rates. An increase in rates is only part, and not even the main part, of this strategy. These rates are in fact a purely quantitative index, which does not always reflect the depth of structural and qualitative transformations. . . . The main point is the shift to a new quality of economic growth."*
- *In May 1987, Georgiy Arbatov, speaking to a US citizen, noted that "the USSR is not looking for economic growth so much as for improved quality."*

In his June 1987 plenum report, Gorbachev suggested that a temporary growth recession might be preferred to high growth rates under certain conditions:

> Fears are being expressed that a temporary decline in production growth rates in individual sectors, regions, and even the country as a whole may take place, given the abandonment of direct directive prescription of volume indicators for associations and enterprises in conditions of complete economic accountability. . . . If it is a question of higher growth figures achieved by cranking up gross volumes, via double counting, and without a real increase in end results, then society not only gains nothing from this, it actually sustains losses.

Later in the speech he implied that growth was not the relevant measure of progress, but rather that the gains from restructuring should be "assessed in terms of end results and the extent to which social needs are satisfied."

Although it is clear from this political rhetoric that quality of output will be an important indicator of Gorbachev's success, it is not clear how much of a growth reduction can or will be tolerated.

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succeeds or fails. If his initiatives ultimately take hold, growth would likely accelerate in the 1990s. Production would not only be at a higher level, but would also be qualitatively superior (see inset). If, on the other hand, his initiatives are thwarted and fail to generate more and better output after the initial period of disruption, then the growth slump would continue and the quality and mix of output would change very little.

The most important—and most uncertain—aspect of simulating the future of the Soviet economy is projecting the returns to new capital and human factors. As shown in the previous section, the range for γ and KPF potentially extends to about 11 percent above pre-1976 levels (in combination with human factors gains). Similarly, the range for HF extends to about

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Table 2
Differences in Assumptions Among the Three Scenarios

Percent

	Gorbachev Doesn't Matter, 1986-2000	Gorbachev Wins		Gorbachev Loses	
		1986-90	1991-2000	1986-90	1991-2000
Trade and end use assumptions *(annual growth rates)*					
Machinery imports	0	1	3	1	1
Machinery exports	3	3	3	3	3
Consumer durables	4	3	5	3	3
Weapons procurement	1	1	1	1	2
Modernization assumptions [a]					
Capital elasticity assumptions [b] *(increase above pre-1986 trends)*					
All but machine building	0	3	15	3	3
Machine building	0	5	25	5	5
Capital productivity factor assumptions [c] *(increase above pre-1986 trends)*	0	2	10	2	2
HF assumptions *(increase above pre-1986 trends)*	0	1	4	1	1

[a] In addition to these assumptions, differing assumptions were made about adjustment costs. In the "Gorbachev doesn't matter" scenario, no adjustment costs were postulated because the modernization program is completely discounted in this scenario. For the "Gorbachev wins" scenario, the relative intensity of the adjustment costs (excluding agriculture) was set as follows: 1986 = 0, 1987 = 0.5, 1988 = 1, 1989-91 = 2, 1992 = 1, and 1993-2000 = 0.

For agriculture, the weighting was delayed (following from historical precedent) and was less intense: 1986-88 = 0, 1989-91 = 1, and 1992-2000 = 0. The same weights were used for the "Gorbachev loses" scenario through 1991, but weights remained at the 1991 level through the year 2000, precluding the recovery simulated in the "Gorbachev wins" scenario. (The actual adjustment costs were determined in the model by multiplying these weights by the slump parameters shown in table 1, which vary by sector of the economy.)

[b] Applies to all sectors except agriculture, services, and electric power.

[c] Applies to services, electric power, and agriculture.

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10 percent above pre-1986 levels. At these levels, Soviet output goals would be realized. The extent to which these modernization parameters will increase because of Gorbachev's initiatives cannot be estimated statistically. Instead, informed judgments were made about the most likely outcome under the assumption that the program is vigorously implemented. Returns in the upper half of these potential ranges are not likely during the current five-year plan because the bulk of Gorbachev's initiatives have yet to be implemented and because of the natural impediments to rapid technological advancement that are characteristic of the Soviet economic system.[34] Nonetheless, some gains are expected.

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[34] These impediments include the lack of incentives to innovate, the lack of quick access to quality information, and the inflexibility of the production process.

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It was assumed in each scenario that the retirement rates and investment allocations planned for the 1990s would not change from those announced by the Soviets for the current five-year plan, and that exogenous factors would remain essentially unchanged to the year 2000. Assumptions underlying the three scenarios are presented in appendix B, and a summary of the differences in assumptions among the three scenarios is presented in table 2. All scenarios incorporate actual economic performance for 1986.

Scenario 1: Gorbachev "Doesn't Matter". In this scenario, no allowance is made for modernization.[35] Energy, raw materials, and transportation constraints become no worse, and trends in labor productivity, the return to capital, exports, imports, and other factors are assumed to continue as they had in 1981-85. It is as if Gorbachev's reform program "doesn't matter"—that is, political rhetoric begets no change in real measurables. Because no serious attempt is made to implement Gorbachev's reform measures in this scenario, adjustment costs were disregarded.

Under these conditions, the average annual growth rate for total GNP would be 2.3 percent in 1986-90, and would then drop to 1.5 percent in the 1990s, assuming average weather (see table 3). When the uncertainties of weather are factored into the analysis (see inset), the most likely range for average growth per year is 1.8 to 2.7 percent for 1986-90 and 1.3 to 1.7 percent for the 1990s. More important, the means of production would basically remain the same, and the same mix of goods would be produced with little improvement in quality or advancement in technology. The 2.3-percent growth rate for the current five-year plan is higher than projected in the following scenarios, where Gorbachev's reforms and initiatives are seriously implemented, but the composition and quality of the goods produced would be inferior. For 1986-90 this outcome can best be described as "growth without progress"; in the 1990s, however, the reduction in growth to below 2 percent would cause the technology gap between the Soviet Union and the West to widen.

[35] This scenario is the same as the baseline scenario used as a reference point in the preceding section.

Table 3
Simulation of Soviet Economic Performance to the Year 2000

Percent

Scenario	Average Annual Growth Rates [a]		
	1986-90	1991-2000	1986-2000
Total GNP [b]			
Gorbachev doesn't matter	**2.3** (1.8-2.7)	**1.5** (1.3-1.7)	**1.8** (1.6-1.9)
Gorbachev wins	**1.9** (1.4-2.3)	**2.9** (2.7-3.1)	**2.6** (2.4-2.7)
Gorbachev loses	**1.9** (1.4-2.3)	**1.6** (1.4-1.8)	**1.7** (1.6-1.8)
Industry			
Gorbachev doesn't matter	2.9	2.7	2.8
Gorbachev wins	2.3	5.5	4.4
Gorbachev loses	2.3	2.9	2.7

[a] Growth rates for 1986-90 use 1985 as a base, and growth rates for 1991-2000 use the estimated value for 1990 as a base. Actual results for 1986 are factored into the analysis.
[b] The point estimate (in boldface) assumes average weather. A most likely range, given in parentheses, was derived by incorporating the uncertainties of weather into the analysis. This range means there is a 10-percent chance that growth could be below the lower limit of the range and a 10-percent chance that it could exceed the upper limit of the range. The base used to calculate the growth rate range for 1991-2000 was the estimated median value for 1990.

Scenario 2: Gorbachev "Wins". This scenario is based on the judgment that significant technological progress can be obtained only by making changes to the Soviet system that would result in considerable disruption for a few years while the system adjusts. During the adjustment period, growth would slow in exchange for the increased ability to produce more and better output in the 1990s. It is as if Gorbachev "wins," but has to pay the price.

For the current five-year plan, we judge that in machine building—where the modernization drive is most sharply focused—an increase in the capital

Incorporating Weather Uncertainties Into Projections of Agricultural Production

Agricultural output—and thus total GNP—largely depends on weather, which cannot be projected precisely. However, information about the frequency of occurrence of past weather events is available and can be used to generate frequency distributions for the weather variables specified in the production function for agriculture. Using these probabilities, a most likely range estimate was determined for net agricultural output. [a]

The uncertainties of weather can be formally incorporated into the analysis with stochastic simulation (also called Monte Carlo analysis). Agricultural output was predicted for each year by randomly choosing values for the weather variables according to a normal distribution with the appropriate mean and variance. The mean and variance for each weather variable were estimated on the basis of an 18-year data set (1969-86). [b] *When the model is solved repeatedly (1,000 times, for example), drawing different values for the weather variables each time, a probability distribution of the output is obtained. A "most likely" range estimate can then be derived from the probability distribution of the estimated output, which reflects the likelihood of all possible weather outcomes and eliminates the need to predict future weather.*

When this method is applied to the baseline scenario (incorporating actual output for 1986 and actual weather data for 1987), the results indicate that there is about an 80-percent chance that the growth rate for average net agricultural output in 1986-90 will be 10.1 to 16.3 percent above the average output for the 1981-85 period. That is, we can conclude that there is about a 10-percent chance that weather will be sufficiently unfavorable to result in growth below 10.1 percent for the five-year period, and about a 10-percent chance weather will be so favorable that growth will exceed 16.3 percent. The midpoint projection (corresponding roughly to "average" weather) is about 13.2 percent—that is, there is a 50-percent probability that the growth rate will be less than 13.2 percent and a 50-percent chance it will be greater than 13.2 percent for the five-year period. The goal for Soviet agriculture as stated in the current five-year plan is "that the average annual volume of agricultural output in 1986-90 should be increased by 14.4 percent over the previous five-year period." [c] *Assuming investment in agriculture is 33.4 billion rubles per year and the decline in agriculture employment is arrested through 1990, there is about a 1-in-3 chance that weather will be favorable enough to attain this goal.* [d]

[a] *Net agricultural output is the sum of the value of total crop production (less seed and waste) and the net value of livestock production (including inventory, excluding feed). See Barbara Severin and Margaret Hughes, Joint Economic Committee, US Congress,* Part III. An Index of Agricultural Production in the USSR, *"USSR: Measures of Economic Growth and Development, 1950-80," December 1982, pp. 245-316. Net agricultural output is converted to value-added units by subtracting the value of intermediate inputs (such as pesticides, fuel and power, feed additives).*

[c] *"Supreme Soviet Decree on Economic Development Law," published in* Izvestiya, *morning edition, p. 1, 20 June 1986.*

[d] *The 1986 plan for state-sector productive investment (excludes collective farms) is 23.2 billion rubles (source:* Planirovaniye i uchet v sel'skokhozyaystvennykh predpriyatiyakh, *No. 2, 1986, p. 6), which is 6 percent above that for 1985. Assuming this growth rate applies to total productive investment in the farm sector, planned 1986 investment would be 33.4 billion rubles. Because of the emphasis on other components of the agroindustrial complex, average annual farm sector investment is not expected to increase above the 1986 level during the current five-year plan.*

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elasticity (γ) for new capital of about 5 percent is possible if the State Acceptance Program and other restructuring initiatives are fully and consistently implemented.[36] This is an average increase that applies to the entire stock of new capital, of which genuinely new products would represent only a small proportion. In addition, it is an average for the entire five-year period. Because the intensity of the reform program is less in other sectors, the increase in the capital elasticity was set at 3 percent, and the increase in the capital productivity factor (KPF) was set at 2 percent for remaining sectors. Similarly, we judge that gains from programs directed toward human factors would increase HF (the productive utility of labor) by an average of about 1 percent for all sectors. Higher gains from human factors would probably not occur before 1990 because of the disruption created by the reforms and the expected low growth of consumer goods.

To simulate the economic disruption, a "slump" period was created for 1987-92 that was roughly equivalent to two consecutive years during the 1976-82 growth slowdown, followed by a complete recovery after 1992.[38] Sectors affected were industry, construction, and agriculture; other sectors were assumed to be unaffected by the disruptions, following historical precedent.

[36] There currently are no indications that Gorbachev's program will not be vigorously implemented. In a speech delivered to a conference of the party Central Committee in July 1987, Gorbachev criticized the civil machine-building industry for insufficient progress in raising the technological level of machinery, declaring that "no retreat is possible" and demanding that Soviet machinery achieve the highest "world standards" in less than seven years

[38] The intensity of the short-run growth slump is determined in the model by the variable "SLUMP." A SLUMP value of 1 indicates that the adjustment costs are equivalent to the average annual downward shift in the production function intercept during the 1976-82 growth slowdown. A value of 2 following a value of 1 indicates that the downward slide in the intercept would continue for one period. For the scenario "Gorbachev wins," SLUMP was set equal to 0.5 in 1987, 1 in 1988, 2 in 1989-91, 1 again in 1992 (simulating a partial recovery), and 0 after 1992 (simulating a complete recovery).

Assuming that this growth slowdown during 1987-92 resulted in legitimate technological progress, increases in the capital elasticities for the 1990s were quintupled (see table 2). In addition, HF was increased an additional three percentage points to 4 percent under the assumption that the gains in modernization would stimulate a sharp increase in worker effort in response to increased availability of better consumer goods, housing, and an upbeat atmosphere in the workplace.[39]

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Because of the economic disruptions during the adjustment period, economic growth for the current five-year plan would be below the rates of recent years, but, in return, growth would increase in the 1990s to rates enjoyed by the Soviets in the early 1970s (see figures 6 and 7). Assuming average weather conditions, average annual GNP growth for 1986-90 would be 1.9 percent, which would then increase by one percentage point to 2.9 percent in the 1990s (see table 3). GNP growth slightly above 3 percent per year is even possible in the 1990s if favorable weather prevails. In industry alone, growth in the 1990s would be more than double that for 1986-90 (see figure 8).[40] More important, the goods produced during the 1990s would be of higher quality, greater diversity, and meet consumer and producer demand more closely.

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[39] To model the additional increase in the return to capital during the 1990s, further model modifications were necessary. Specifically, the two-period vintage capital model presented earlier was expanded to a three-period vintage capital model. The equations used for the production functions for the 1990s—under the assumption that the modernization program essentially succeeds—are:

$$Q = \alpha(t)[K_o^{\beta}(HF \times L_o)^{1-\beta} + Kn_1^{\gamma}(HF \times Ln_1)^{1-\gamma} + Kn_2^{\delta}(HF \times Ln_2)^{1-\delta}],$$

and

$$Q = \alpha(t)[K_o^{\beta}(HF \times L_o)^{1-\beta} + (KPF_1 \times Kn_1)^{\beta}(HF \times Ln_1)^{1-\beta} + (KPF_2 \times Kn_2)^{\beta}(HF \times Ln_2)^{1-\beta}],$$

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where

- Kn_1 = capital stock of 1986-90 vintage,
- Kn_2 = capital stock of 1991-2000 vintage,
- Ln_1 = labor required for the 1986-90 vintage capital,
- Ln_2 = labor available for the 1991-2000 vintage capital,
- δ = capital elasticity for 1991-2000 vintage capital, and
- KPF_2 = capital productivity factor for 1991-2000 vintage capital.

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[40] Average investment growth for 1986-90 in this scenario roughly corresponds to the Soviet's target of 5 percent per year, which is about twice as high as would be obtained under the assumptions of the "Gorbachev doesn't matter" scenario.

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Figure 6
Projections of Soviet GNP

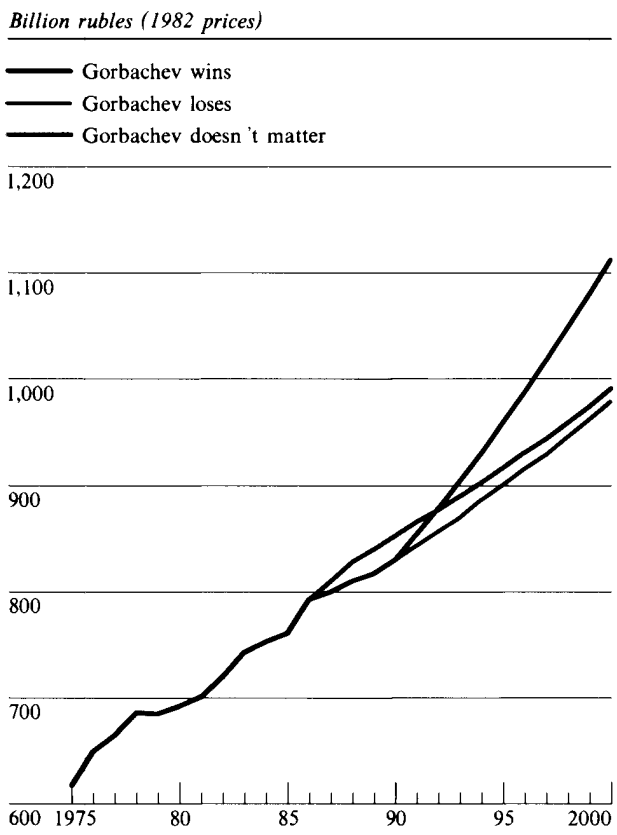
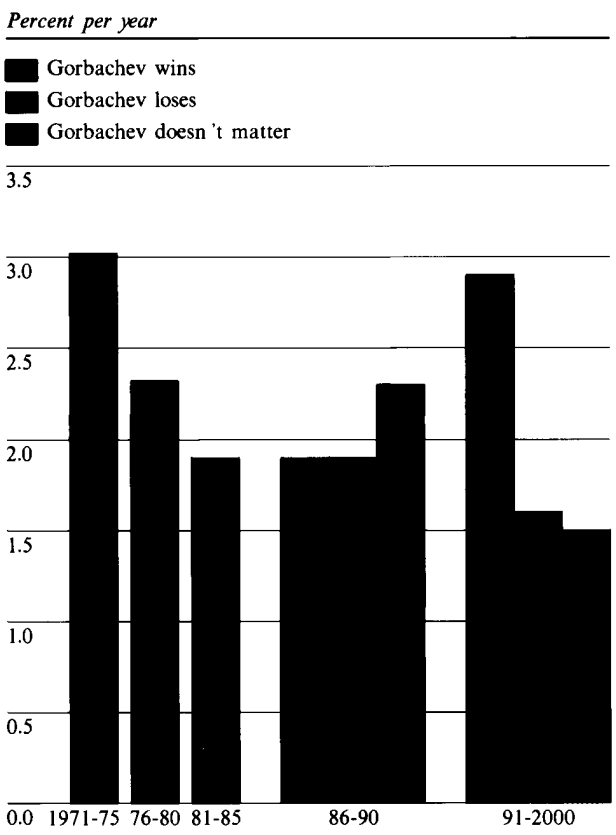


Figure 7
Total GNP: Average Annual Growth[a]



[a]Growth rates for 1986-90 use 1985 as a base. Growth rates for 1991-2000 use estimated GNP for 1990 as a base. Projected growth rates for 1986-90 include actual results for 1986.

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Scenario 3: Gorbachev "Loses." The third scenario mimics the previous scenario through the 1986-90 period, but postulates that Gorbachev's programs, while implemented, fail to raise technology to a more efficient level. Economic disruptions occur, but there is no recovery from the 1987-90 slump, and consequently no payoff of higher productivity in the 1990s. This situation could arise if new programs further distort economic mechanisms, moving production technologies to a less efficient level—more redtape instead of less, for example. Political turmoil and frequent changes in objectives could contribute to the permanent slump. In addition, it is assumed that bottlenecks worsen, possibly because of capacity constraints in transportation and energy production or an increased drain of resources to the military. Some gains in human factors and return to capital are postulated (equal to those in the 1986-90 period in the previous scenario), but no additional gains occur in the 1990s.

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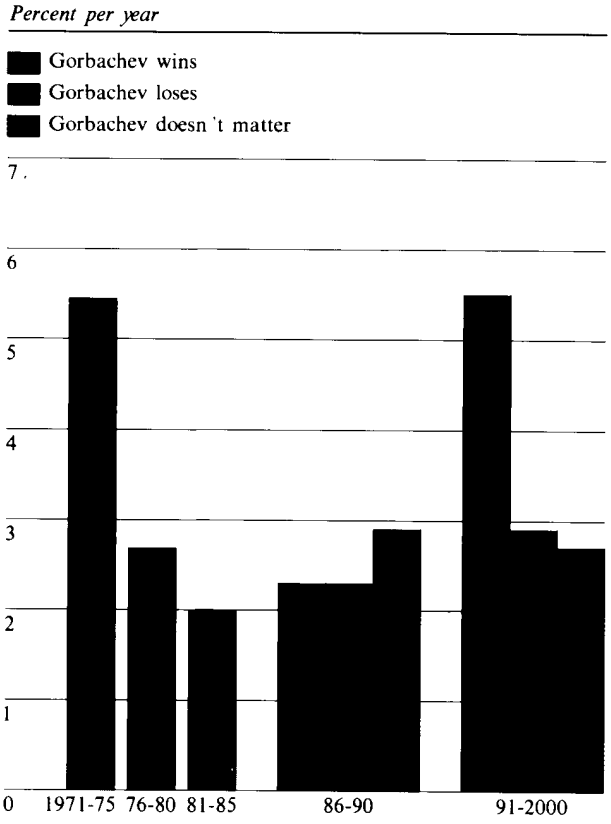
Figure 8
Industry: Average Annual Growth [a]



[a]Growth rates for 1986-90 use 1985 as a base. Growth rates for 1991-2000 use estimated GNP for 1990 as a base. Projected growth rates for 1986-90 include actual results for 1986.

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In this scenario, the average annual growth rate for GNP for 1986-90 would be the same as in the previous scenario, 1.9 percent (assuming average weather conditions). This would be followed by an average annual growth rate of 1.6 percent in the 1990s, approximately equivalent to performance under the assumptions of the "Gorbachev doesn't matter" scenario. The means of production would change slightly for the better, and the product mix and quality of goods would increase some, but overall, Gorbachev's attempts to modernize the Soviet economy would fail. This failure would be reflected in the continuation of low growth throughout the 1990s. By the year 2000, the difference between "winning" and "losing" amounts to 133 billion rubles per year—equivalent to total investment in the economy in 1976.

25X1

Conclusion

There are, of course, possibilities for Soviet economic growth other than those presented above. Gains from the modernization drive may be more or less than those used in the "Gorbachev wins" and "Gorbachev loses" scenarios. The costs of adjustment associated with those gains may vary (for example, see inset, table 4, and figure 9) and factors outside the control of Moscow can affect economic growth. For example, GNP growth in the 1990s can vary by nearly one-half a percentage point depending on weather alone, and could vary by nearly a full percentage point during the 1986-90 period owing to weather. Furthermore, given the historical precedent, it is hard to imagine a more rapid pace for restructuring than the one Gorbachev has proposed, which was simulated in these scenarios. A likely outcome would be a more prolonged time frame for restructuring, which would in turn delay the gains from modernization.

25X1

These simulations strongly suggest, however, that the Soviet growth goals of 4 to 5 percent per year through the end of the century—if measured in real terms—cannot be achieved. If Gorbachev's program is not seriously implemented, near-term prospects for growth will closely reflect those in recent years. If his program is vigorously implemented, near-term prospects for growth look poor. However, if his program is successful, growth prospects in the 1990s could potentially approach the relatively high rates of the early 1970s—about 3 percent per year—but would still fall short of Soviet plans. And finally, if his program is implemented more slowly than he plans—perhaps in reaction to unacceptably high adjustment costs and associated low growth rates—gains from modernization will be stretched out over a longer period of time, resulting in overall growth intermediate to rates shown here for the "Gorbachev wins" and "Gorbachev loses" scenarios.

25X1

25X1

Impact of Adjustment Costs on Soviet GNP Growth

The extent and duration of the temporary disruption period is difficult to project. It depends on how fast the changes are made and how disruptive they will be.

For the "Gorbachev wins" and "Gorbachev loses" scenarios, adjustment costs were modeled by approximating the value of foregone production during the first two years of the 1976-82 industrial growth slowdown. It was assumed that these adjustment costs would begin in 1987, peak in 1989-91, and—in the "Gorbachev wins" scenario—recover completely by 1993. For this scenario, the base level of adjustment costs amounts to about 150 billion rubles (1982 prices) when totaled over 1986-2000. [a] *However, other patterns of adjustment costs are possible.*

Simulation results indicated that, although the overall 15-year growth rate was invariant to changes in the pattern of adjustment costs, growth rate projections for 1986-90 varied significantly. Two additional scenarios were created that repeated all assumptions in the "Gorbachev wins" scenario, except that the pattern of adjustment costs was allowed to vary while holding the total costs equal to 150 billion rubles. A shorter but deeper adjustment cost path resulted in a 1.6-percent annual GNP growth rate for 1986-90, whereas a longer but shallower path resulted in 2.3-percent growth (compared with 1.9-percent growth for the "Gorbachev wins" scenario presented in the text). The difference between 1.6- and 2.3-percent growth is perhaps large enough to have political significance and suggests that Gorbachev could minimize the political cost by stretching out the adjustment period (see table 4). Indeed, comparison of his rhetoric and actions suggests he may be doing just that—calling for revolutionary changes (by Soviet standards) but compromising on their implementation.

It is also possible that even greater adjustment costs will be necessary to achieve the modernization gains simulated in the "Gorbachev wins" scenario. Additional simulations showed that doubling and quadrupling the total adjustment costs by deepening the adjustment cost path and—for the latter scenario—extending it through 1995 resulted in only a marginal reduction in the average annual growth rate for the 15-year projection period (see table 4). Although growth in the 1986-90 period was quite low for these two scenarios, gains from modernization in the 1990s more than offset the additional adjustment costs. When compared with the "Gorbachev wins" scenario presented in the text, GNP in the year 2000 was only 12 billion rubles lower when total adjustment costs were doubled, and 32 billion rubles lower when total adjustment costs were quadrupled. In spite of these reductions, however, GNP in the year 2000 was still 110 and 90 billion rubles per year, respectively, higher than would be obtained under the "Gorbachev doesn't matter" scenario (see figure 9).

The conclusion we can draw from these additional simulations is that improved growth in the 1990s is expected regardless of the extent or duration of the adjustment period, assuming that Gorbachev's modernization drive is vigorously implemented and significant modernization occurs.

[a] *This was determined by comparing total GNP for 1986-2000 for the "Gorbachev wins" scenario to an identical scenario with all adjustment costs excluded (that is, SLUMP = 0 for the entire projection period).*

25X1

Table 4
Economic Adjustment Costs

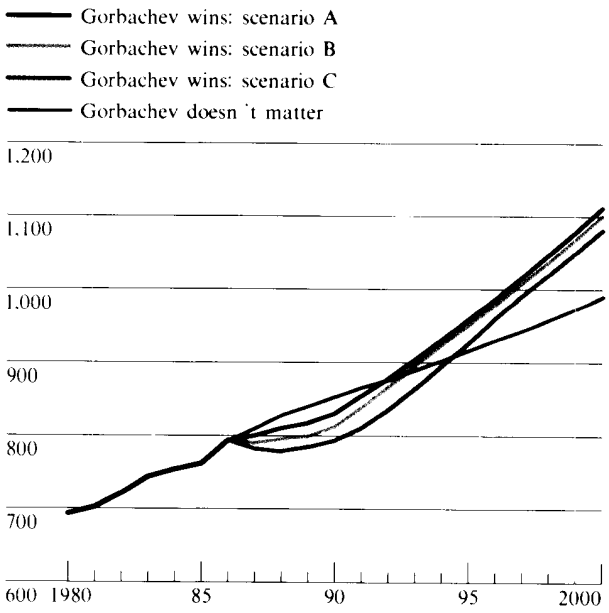
Percent

	Average Annual Growth Rates [a]		
	1986-90	1991-2000	1986-2000
Gorbachev wins (scenario A) [b]	1.9	2.9	2.6
Shorter but deeper adjustment cost path	1.6	3.0	2.6
Longer but shallower adjustment cost path	2.3	2.7	2.6
Total adjustment costs = 2 × base level (scenario B)	1.4	3.0	2.5
Total adjustment costs = 4 × base level (scenario C)	1.0	3.0	2.4

[a] Growth rates for 1986-90 use 1985 as a base, and growth rates for 1991-2000 use the estimated value for 1990 as a base. Actual results for 1986 are factored into the analysis.
[b] Base level = 150 billion rubles.

Figure 9
Effect of Increased Adjustment Costs on GNP

Billion rubles (1982 prices)



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25X1

25X1

Appendix A

Statistical Results for Estimates of Production Function Parameters

Parameter estimates and statistical results for production functions used in CIA's macroeconomic model of the Soviet Union are presented in this appendix's first section. The rationale for the functional forms used is presented in the main text's section "Measuring the Return to Capital." Data used to estimate the parameters are in the second section of this appendix.

25X1

Production Function for Transportation and Communications

Model

Log(Q/L) = INTERCEPT + A1 × log(K/L) + A2 × DUM6976 + A3 × DUMSLOPE,

where DUM6976 = dummy variable for 1969-76,
DUMSLOPE = interaction term for DUM6976 and log(K/L).

Analysis of Variance

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Significance of F	Adjusted R^2
Model	3	0.227173	0.075724	1,930	0.0001	0.9972
Error	13	0.000509	0.000039			
Corrected total	16	0.227683				

Parameter Estimates

Variable	Parameter Estimate	Standard Error	T for HO: Parameter = 0	Probability > [T]
INTERCEPT	0.502982	0.038606	13.02	0.0001
Log(K/L)	0.329566	0.015977	20.62	0.0001
DUM6976	−0.872044	0.055391	−15.74	0.0001
DUMSLOPE	0.408494	0.025475	16.03	0.0001

25X1

Production Function for Fuels

Model

$$\text{Log}(Q/L) = \text{INTERCEPT} + A1 \times \log(K/L) + A2 \times \text{DUM6977} + A3 \times \text{DUMSLOPE} + A4 \times \text{DUM7882},$$

where DUM6977 = dummy variable for 1969-77,
DUMSLOPE = interaction term for DUM6977 and log(K/L),
DUM7882 = dummy variable for 1978-82.

Analysis of Variance

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Significance of F	Adjusted R^2
Model	4	0.608434	0.152109	3,689	0.0001	0.9989
Error	12	0.000494	0.000041			
Corrected total	16	0.608929				

Parameter Estimates

Variable	Parameter Estimate	Standard Error	T for HO: Parameter = 0	Probability > [T]
INTERCEPT	2.156876	0.097091	22.21	0.0001
Log(K/L)	0.039291	0.026933	1.45	0.1703
DUM6977	−2.202211	0.100572	−21.89	0.0001
DUMSLOPE	0.698616	0.028569	24.45	0.0001
DUM7882	−0.032809	0.009967	−3.29	0.0064

25X1

Production Function for Chemicals

Model

Log(Q/L) = INTERCEPT + A1 × log(K/L)+ A2 × DUM8285 + A3 × TDUM7881,

where TDUM7881 = time-dummy interaction variable for 1978-81,
DUM8285 = dummy variable for 1982-85.

Analysis of Variance

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Significance of F	Adjusted R^2
Model	3	0.485367	0.161789	716	0.0001	0.9926
Error	13	0.002938	0.000226			
Corrected total	16	0.488306				

Parameter Estimates

Variable	Parameter Estimate	Standard Error	T for HO: Parameter = 0	Probability > [T]
INTERCEPT	−0.154079	0.055337	−2.78	0.0155
Log(K/L)	0.727752	0.024315	29.93	0.0001
TDUM7881	−0.050993	0.005060	−10.07	0.0001
DUM8285	−0.230439	0.019738	−11.67	0.0001

25X1

Production Function for Consumer Goods

Model

$$\text{Log}(Q/L) = \text{INTERCEPT} + A1 \times \log(K/L) + A2 \times \text{DUM8285} + A3 \times \text{TDUM7681},$$

where TDUM7681 = time-dummy interaction variable for 1976-81,
DUM8285 = dummy variable for 1982-85.

Analysis of Variance

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Significance of F	Adjusted R^2
Model	3	0.171327	0.057109	1179	0.0001	0.9955
Error	13	0.000629	0.000048			
Corrected total	16	0.171956				

Parameter Estimates

Variable	Parameter Estimate	Standard Error	T for HO: Parameter = 0	Probability > [T]
INTERCEPT	0.351256	0.014870	23.62	0.0001
Log(K/L)	0.422763	0.015811	26.73	0.0001
TDUM7681	−0.007542	0.001723	−4.37	0.0007
DUM8285	−0.054115	0.010850	−4.98	0.0002

25X1

Production Function for Electric Power

Model

$$\text{Log}(Q/L) = \text{INTERCEPT} + A1 \times \log(K/L) + A2 \times \text{DUM8285} + A3 \times \text{TDUM7781},$$

where TDUM7781 = time-dummy interaction variable for 1977-81,
DUM8285 = dummy variable for 1982-85.

Analysis of Variance

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Significance of F	Adjusted R^2
Model	3	0.385107	0.128369	1838	0.0001	0.9971
Error	13	0.000907	0.000069			
Corrected total	16	0.386015				

Parameter Estimates

Variable	Parameter Estimate	Standard Error	T for HO: Parameter = 0	Probability > [T]
INTERCEPT	−0.990305	0.070887	−13.97	0.0001
Log(K/L)	0.891543	0.018914	47.13	0.0001
TDUM7781	−0.015004	0.002032	−7.38	0.0001
DUM8285	−0.113723	0.009306	−12.22	0.0001

25X1

Production Function for Industrial Materials

Model

Log(Q/L) = INTERCEPT + A1 × log(K/L) + A2 × DUM8285 + A3 × TDUM7681,

where TDUM7681 = time-dummy interaction variable for 1976-81,
DUM8285 = dummy variable for 1982-85.

Analysis of Variance

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Significance of F	Adjusted R^2
Model	3	0.062469	0.020823	382	0.0001	0.9871
Error	12	0.000653	0.0000544			
Corrected total	15	0.063123				

Parameter Estimates

Variable	Parameter Estimate	Standard Error	T for HO: Parameter = 0	Probability > [T]
INTERCEPT	0.503847	0.032994	15.27	0.0001
Log(K/L)	0.454937	0.018635	24.41	0.0001
TDUM7681	−0.026580	0.002100	−12.65	0.0001
DUM8285	−0.206234	0.013142	−15.69	0.0001

25X1

Production Function for Machine Building

Model

Log(Q/L) = INTERCEPT + A1 × log(K/L) + A2 × DUM8385 + A3 × TDUM7782
+ A4 × DUM7172,

where TDUM7782 = time-dummy interaction variable for 1977-82,
DUM8385 = dummy variable for 1983-85,
DUM7172 = dummy variable for 1971-72.

Analysis of Variance

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Significance of F	Adjusted R^2
Model	4	0.220987	0.055247	453	0.0001	0.9912
Error	12	0.001464	0.000122			
Corrected total	16	0.222451				

Parameter Estimates

Variable	Parameter Estimate	Standard Error	T for HO: Parameter = 0	Probability > [T]
INTERCEPT	0.343138	0.022384	15.32	0.0001
Log(K/L)	0.523432	0.021933	23.86	0.0001
TDUM7782	−0.027334	0.002926	−9.34	0.0001
DUM8385	−0.214263	0.017921	−11.95	0.0001
DUM7172	−0.041268	0.009246	−4.46	0.0008

25X1

Production Function for Construction

Model

$$\text{Log}(Q/L) = \text{INTERCEPT} + A1 \times \log(K/L) + A2 \times \text{DUM7680} + A3 \times \text{DUM7779} + A4 \times \text{DUM6971},$$

where DUM7680 = dummy variable for 1976-80,
DUM7779 = dummy variable for 1977-79,
DUM6971 = dummy variable for 1969-71.

Analysis of Variance

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Significance of F	Adjusted R^2
Model	4	0.174808	0.043702	1,615	0.0001	0.9975
Error	12	0.000324	0.000027			
Corrected total	16	0.175132				

Parameter Estimates

Variable	Parameter Estimate	Standard Error	T for HO: Parameter = 0	Probability > [T]
INTERCEPT	0.716375	0.004180	171.37	0.0001
Log(K/L)	0.285576	0.004429	64.47	0.0001
DUM7680	−0.022500	0.004075	−5.52	0.0001
DUM7779	−0.042179	0.003474	−12.13	0.0001
DUM6971	0.020202	0.004509	4.48	0.0008

25X1

Production Function for Services

Model

$$\text{Log}(Q/L) = \text{INTERCEPT} + A1 \times \log(K/L) + A2 \times \text{DUM76} + A3 \times \text{DUM7275},$$

where DUM76 = dummy variable for 1976,
DUM7275 = dummy variable for 1972-75.

Analysis of Variance

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Significance of F	Adjusted R^2
Model	3	0.011406	0.003802	1,094	0.0001	0.9961
Error	10	0.000034	0.000003			
Corrected total	13	0.011441				

Parameter Estimates

Variable	Parameter Estimate	Standard Error	T for HO: Parameter = 0	Probability > [T]
INTERCEPT	0.334064	0.009299	35.92	0.0001
Log(K/L)	0.197748	0.005554	35.59	0.0001
DUM7275	0.010538	0.002007	5.24	0.0004
DUM76	0.005792	0.002290	2.52	0.0300

25X1

Production Function for Domestic Trade and Other Sectors

Model

$$\text{Log}(Q/L) = \text{INTERCEPT} + A1 \times \log(K/L)$$

Analysis of Variance

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Significance of F	Adjusted R^2
Model	1	0.022832	0.022832	808	0.0001	0.9841
Error	12	0.000339	0.000028			
Corrected total	13	0.023171				

Parameter Estimates

Variable	Parameter Estimate	Standard Error	T for HO: Parameter = 0	Probability > [T]
INTERCEPT	0.683270	0.006405	106.67	0.0001
Log(K/L)	0.175383	0.006170	28.42	0.0001

25X1

Production Function for Housing

Model

$\text{Log}(Q) = \text{INTERCEPT} + A1 \times \log(K)$

Analysis of Variance

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Significance of F	Adjusted R^2
Model	1	0.233251	0.233251	12,347	0.0001	0.9987
Error	15	0.000283	0.000018			
Corrected total	16	0.233534				

Parameter Estimates

Variable	Parameter Estimate	Standard Error	T for HO: Parameter = 0	Probability > [T]
INTERCEPT	0.688387	0.024336	28.28	0.0001
Log(K)	0.478880	0.004309	111.11	0.0001

25X1

Data Base

	Machine Building			Construction			Fuels		
	Q	L	K	Q	L	K	Q	L	K
1969	43.37	21.41	42.63	34.21	15.68	18.05	14.92	2.68	29.30
1970	46.05	21.90	47.09	36.93	16.52	20.70	15.81	2.64	31.74
1971	48.01	22.64	52.58	39.20	17.54	22.70	16.63	2.63	34.34
1972	50.15	23.17	57.86	41.02	18.30	25.05	17.47	2.55	36.70
1973	55.07	23.64	63.63	42.76	18.37	28.05	18.41	2.49	39.25
1974	60.05	24.40	70.08	44.33	18.87	31.05	19.40	2.48	42.39
1975	63.95	25.15	77.18	46.01	19.26	33.70	20.56	2.48	45.79
1976	67.53	26.02	85.02	46.84	19.51	36.40	21.42	2.48	49.40
1977	70.40	26.63	93.83	47.29	19.76	40.40	22.36	2.40	53.15
1978	73.10	27.06	102.46	49.70	19.95	44.75	23.15	2.45	56.94
1979	75.41	27.52	111.92	50.97	20.13	49.40	23.80	2.51	61.78
1980	77.33	27.84	121.61	53.12	20.23	53.05	24.30	2.54	67.17
1981	77.47	28.01	132.08	55.51	20.28	56.75	24.62	2.57	73.13
1982	77.34	28.24	142.41	56.94	20.23	62.10	25.05	2.62	79.51
1983	78.74	28.46	153.08	58.69	20.23	67.75	25.38	2.55	86.78
1984	80.89	28.71	164.10	59.89	20.32	72.40	25.59	2.56	94.36
1985	84.28	28.90	175.43	61.39	20.59	76.05	25.76	2.59	102.08

Note: Q = output in billions of 1982 rubles, measured at factor cost.

L = employment in billions of worker-hours estimated by the US Bureau of the Census, Center for International Research [CIR].

K = capital in billions of 1973 rubles.

Capital stock data represent midyear values and were determined from end-of-year data (which were published by the Soviets or were estimated using Soviet statistics) as follows:

$$K = K^*_{-1} + .35 \times K^*,$$

where K* represents end-of-year capital stock data.

Data Base (continued)

	Consumer Goods			Chemicals			Industrial Materials		
	Q	L	K	Q	L	K	Q	L	K
1969	27.24	14.40	28.90	9.42	2.68	18.53	45.00	14.36	62.91
1970	28.75	14.58	31.13	10.47	2.77	20.88	48.04	14.33	67.51
1971	29.76	14.73	33.34	11.16	2.83	23.50	50.17	14.50	73.02
1972	30.48	14.65	35.88	11.88	2.86	25.77	51.95	14.75	79.83
1973	30.97	14.62	38.85	12.92	2.92	28.18	54.37	14.69	85.97
1974	32.62	14.79	42.01	14.17	3.00	31.01	56.60	14.80	92.83
1975	33.99	14.80	44.88	15.57	3.08	33.91	59.30	14.94	101.88
1976	34.45	15.05	47.78	16.25	3.15	36.92	60.55	15.05	111.49
1977	35.58	15.24	50.74	17.04	3.17	39.87	61.25	15.23	119.38
1978	36.01	15.28	53.58	17.55	3.26	42.86	62.14	15.38	128.32
1979	36.74	15.31	56.65	17.37	3.28	47.29	61.71	15.49	136.68
1980	37.29	15.33	59.88	18.05	3.32	52.48	62.19	15.58	144.59
1981	38.10	15.39	63.51	18.73	3.35	57.20	62.75	15.71	154.99
1982	38.59	15.35	67.19	19.10	3.38	61.58	62.79	15.93	165.56
1983	39.52	15.34	70.91	20.22	3.41	65.75	64.71	16.01	175.83
1984	40.47	15.28	74.64	20.90	3.41	70.30	66.04	16.11	187.69
1985	40.57	15.16	78.51	21.80	3.44	74.73	67.60	16.26	199.56

Data Base (continued)

	Services			Trade and Other Sectors			Transportation and Communications		
	Q	L	K	Q	L	K	Q	L	K
1969	63.72	35.35	106.80	33.44	15.89	27.70	44.18	16.61	103.80
1970	66.42	36.46	116.55	35.78	16.39	29.70	47.23	17.02	111.80
1971	69.22	37.94	130.95	37.40	17.05	30.30	50.60	17.64	120.15
1972	72.01	39.26	145.85	38.55	17.62	31.45	53.39	18.13	129.85
1973	74.57	40.43	157.20	40.42	18.17	36.35	57.18	18.53	140.50
1974	77.51	41.73	168.15	42.33	18.77	39.10	61.14	19.03	151.20
1975	80.29	42.97	177.50	44.10	19.26	44.40	64.87	19.59	163.20
1976	82.21	43.86	188.55	45.89	19.59	48.40	68.00	19.92	174.85
1977	84.37	44.86	201.90	47.27	20.00	52.40	69.27	20.33	186.55
1978	86.94	45.87	215.55	47.95	20.30	56.05	72.44	20.75	199.90
1979	89.77	47.12	229.60	49.14	20.58	59.40	74.78	21.17	213.90
1980	92.99	48.18	244.90	50.26	20.88	63.40	77.83	21.54	227.90
1981	95.34	48.94	258.90	51.15	21.09	67.40	81.02	21.87	242.25
1982	96.68	49.44	273.60	51.35	21.19	71.05	82.10	22.12	257.60
1983	98.66	49.92	289.95	52.69	21.27	74.75	84.47	22.26	274.30
1984	101.05	50.67	306.60	53.83	21.51	79.40	85.98	22.39	292.30
1985	103.41	51.47	322.95	54.27	21.72	83.40	87.95	22.51	310.30

Data Base (continued)

	Electric Power			Housing	
	Q	L	K	Q	K
1969	9.88	1.18	38.36	24.29	187.50
1970	10.64	1.18	42.33	24.99	197.50
1971	11.50	1.21	46.26	25.69	207.50
1972	12.32	1.21	50.00	26.38	218.20
1973	13.15	1.22	53.86	27.07	230.55
1974	14.03	1.24	57.46	27.76	243.90
1975	14.95	1.27	61.20	28.46	257.90
1976	15.98	1.30	65.23	29.12	271.55
1977	16.55	1.33	69.16	29.77	284.90
1978	17.32	1.36	73.07	30.45	299.25
1979	17.83	1.39	77.57	31.08	313.90
1980	18.63	1.44	82.25	31.71	328.25
1981	19.09	1.46	87.07	32.38	343.60
1982	19.68	1.50	91.73	33.30	359.95
1983	20.42	1.53	96.68	34.25	377.65
1984	21.48	1.56	101.63	35.12	397.00
1985	22.23	1.59	107.05	35.99	417.35

25X1

Appendix B

Assumptions Underlying the Modeling Results

Assumptions underlying the three scenarios differ only with respect to the success of Gorbachev's modernization program and its impact on machinery imports, production of consumer durables, and weapons procurement costs. Other exogenous variables and coefficients were held constant for all scenarios. Capital retirement rates and the allocation of investment among sectors were determined on the basis of levels the Soviets planned for 1986-90. Values for most other parameters and exogenous variables were set to reflect recent trends (1981-85 in most cases).

Assumptions Common to All Scenarios

Investment shares were derived from an estimated structure of Soviet capital investment for 1986-90.[1] These rates were extended to the 1991-2000 period under the assumption that the modernization drive would continue to be the top priority throughout the 1990s. Information leading directly to calculation of shares for the chemicals, fuels, electric power, transportation and communications, and housing sectors—as well as the productive and nonproductive totals—were given in Soviet speeches. For agriculture, investment was set at 33.4 billion rubles per year, rather than fixing the share (equivalent to a total of 167 billion rubles for 1986-90.) Investment shares for domestic trade, consumer goods, and industrial materials were set at the 1981-85 level, indicating no increase in priority for these sectors. The share for construction was assumed to be 4 percent, a slight increase above the 1981-85 level. The machine-building share was determined by assuming an 80-percent increase in investment to civilian ministries (a stated goal for 1986-90) and a 27.5-percent increase in military ministries. (Use of 27.5 percent here—together with the other assumptions noted above—balances investment in the productive sectors with the planned total.)[2] 25X1

Retirement rates for 1986-90 were increased above the 1985 level on the basis of the Soviet plan for total retirements. Retirement rates for 1985 were calculated from data on retirements and yearend capital stock reported in the 1985 *Narkhoz* (pp. 51 and 124). Except for machine building, agriculture, and construction, these rates were increased at constant annual increments such that the 1990 rates were 75 percent of the planned retirement rate for 1990.[3] Retirement rates for 1991-2000 were held constant at the 1990 level. For machine building, information on planned retirement of the machinery and equipment components was incorporated into the 1986-90 estimate. For agriculture and construction, the average of the 1982-85 retirement rate was applied to the entire projection period. In the case of construction, the retirement rate for 1991-2000 was reduced after 1990 because of the rapid depletion of pre-1986 vintage capital stock. 25X1 25X1

The principal assumptions common to all scenarios are summarized in table B-3. Other assumptions include: 25X1

[1] See Robert E. Leggett, "Soviet Investment Policy: The Key to Gorbachev's Program for Revitalizing the Soviet Economy," Joint Economic Committee, US Congress, *Gorbachev's Economic Plans*, Congress of the United States, forthcoming.

[2] Relative to the 1985 investment allocation, investment shares for 1986-90 are higher for machine building, chemicals, construction, and housing, and are lower for agriculture, services, and transportation and communications. Investment shares for remaining sectors are essentially unchanged. 25X1

[3] The planned retirement rate for all productive capital is 3.1 percent by 1990, which is a 47-percent increase over the 2.1-percent rate for 1985. If only 75 percent of the planned goal is achieved, as assumed here, the overall retirement rate will increase 36 percent by 1990. 25X1

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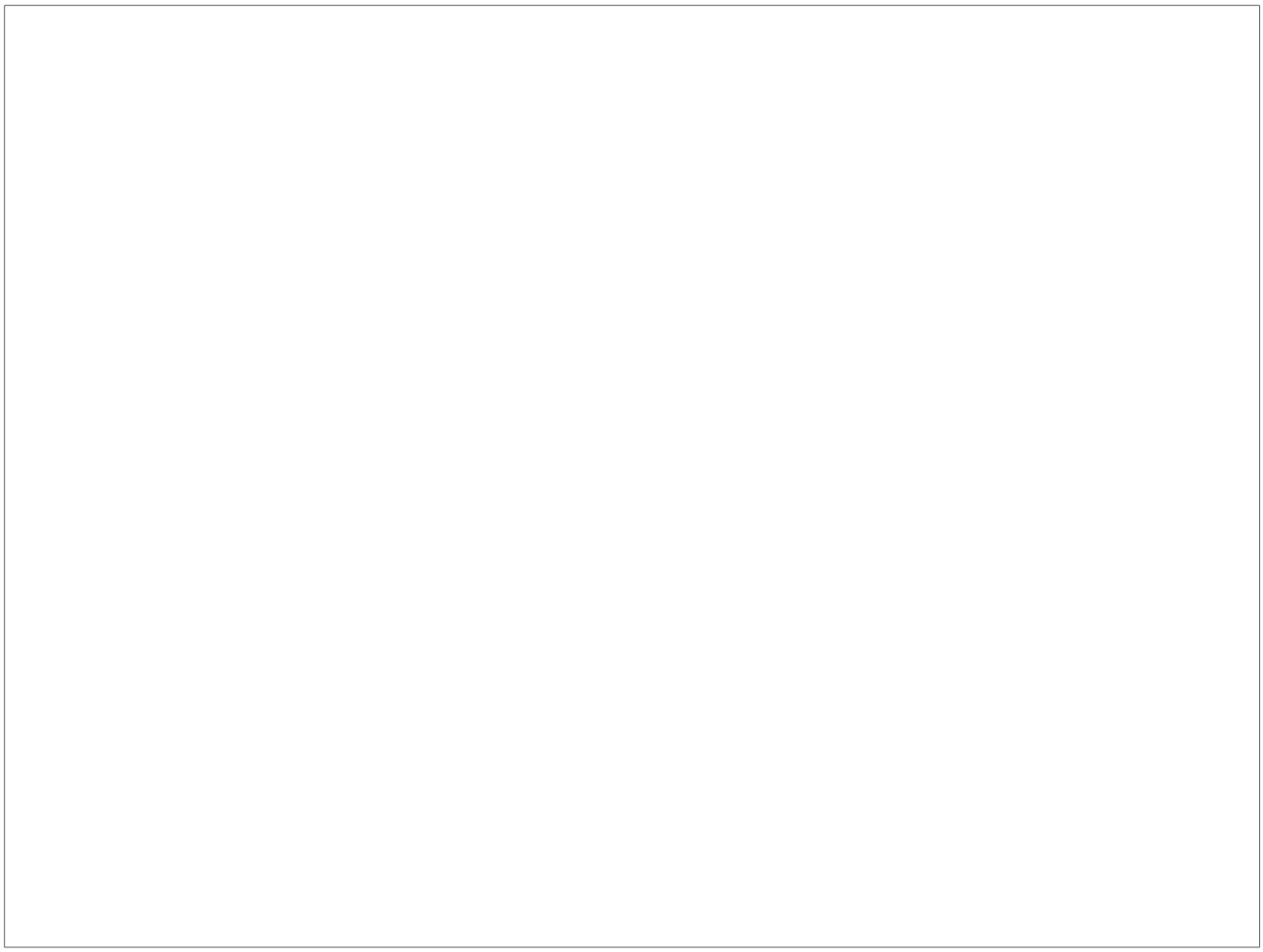

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- The coefficients that convert investment in 1984 prices into global commissionings in 1973 prices were derived from data for 1981-85. Coefficients converting machine-building and construction output to final use were set so that new fixed investment for 1986 grew at the 1986 plan rate of 7.6 percent.

- The relationship between capital repair and the capital stock was derived from data for 1976-85. Capital less than five years old is exempt from repair costs.

- Stochastic simulation was used to generate weather variables according to a frequency distribution based on an 18-year data set (1969-86).

- Agricultural purchases from other sectors of the economy were set to grow at 4 percent per year.

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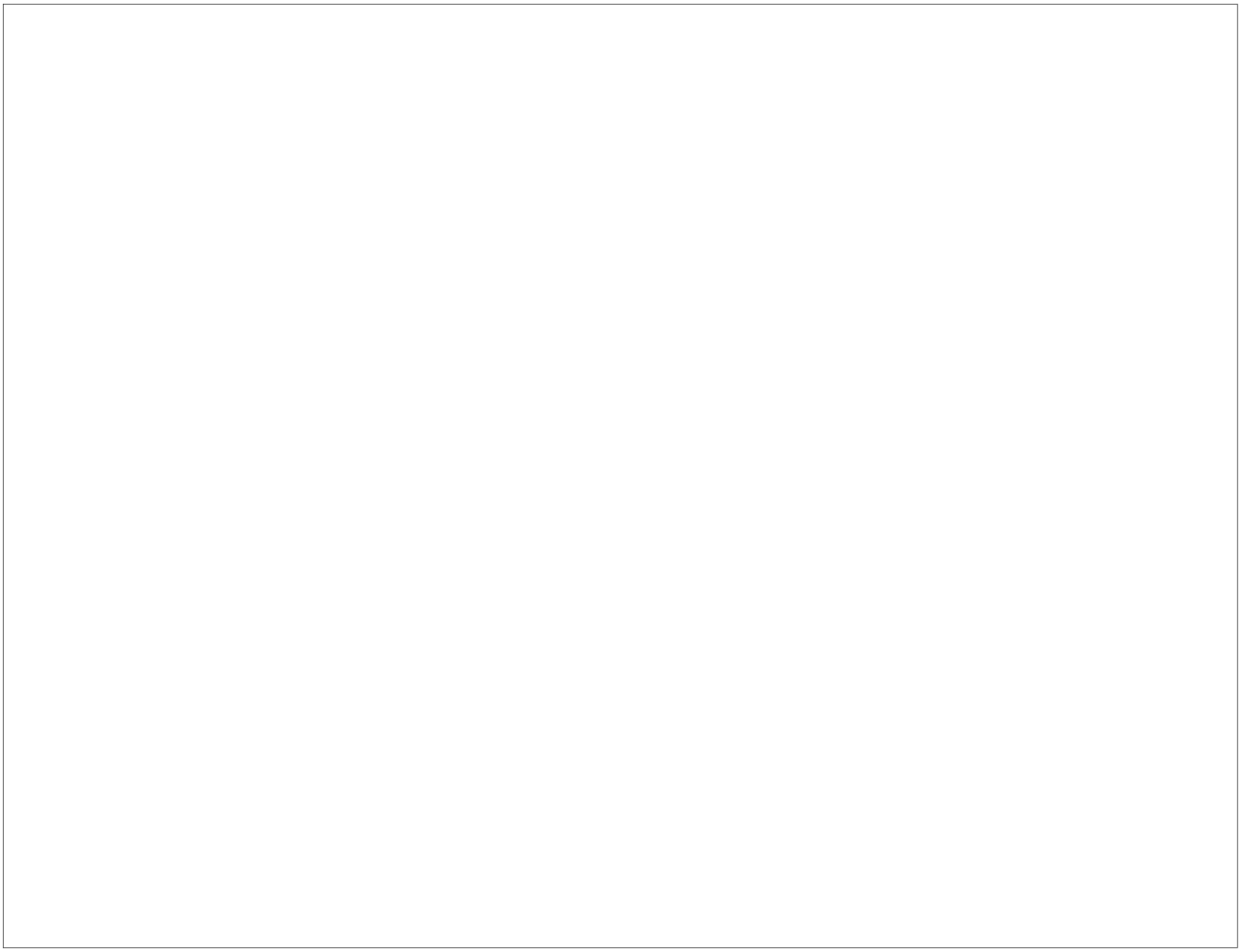
In addition, estimating the capital elasticity on the basis of a particular historical period creates several implicit assumptions about production. For example,



25X1

no adjustment is made—apart from adjustment costs stemming from the modernization drive—for increases or decreases in capital utilization (which might result from changes in energy availability, or a sudden increase in the retirement of unused capital). The implicit assumption here is that all factors not included specifically in the production function are assumed to remain at the long-term "average" throughout the projection period.[4] Thus, capital utilization rates, energy contraints, supply disruptions, the effects of weather, labor hoarding by enterprises, and the relative cost of material inputs—other than those that occurred during the growth slowdown period—are assumed to persist at present levels or rates throughout 1986-2000.

25X1

Differences Among Scenarios

To be consistent with the outcome of Gorbachev's program, the three scenarios differed slightly for machinery imports, production of consumer durables, and the cost of weapons procurement

25X1

In constructing the "baseline" scenario (also labeled

25X1

[4] In addition, assumptions associated with estimating output in factor cost prices automatically extend to the capital elasticity estimate.

Table B-3
Common Scenario Assumptions, Retirement Rates

	Machine Building	Chemicals	Consumer Goods	Construction	Transportation and Communications	Electric Power
1986	0.020	0.013	0.022	0.069	0.013	0.0043
1987	0.027	0.014	0.024	0.069	0.014	0.0046
1988	0.033	0.015	0.025	0.069	0.015	0.0048
1989	0.040	0.015	0.026	0.069	0.016	0.0051
1990	0.046	0.016	0.028	0.069	0.016	0.0054
1991	0.046	0.016	0.028	0.060	0.016	0.0054
1992	0.046	0.016	0.028	0.060	0.016	0.0054
1993	0.046	0.016	0.028	0.060	0.016	0.0054
1994	0.046	0.016	0.028	0.060	0.016	0.0054
1995	0.046	0.016	0.028	0.060	0.016	0.0054
1996	0.046	0.016	0.028	0.040	0.016	0.0054
1997	0.046	0.016	0.028	. . .[a]	0.016	0.0054
1998	0.046	0.016	0.028	. . .[a]	0.016	0.0054
1999	0.046	0.016	0.028	. . .[a]	0.016	0.0054
2000	0.046	0.016	0.028	. . .[a]	0.016	0.0054

Footnote appears at end of table.

"Gorbachev doesn't matter"), it was assumed that these variables would continue to grow at present rates. Thus, machinery imports were set at zero growth, consumer durables were set at 4-percent growth, and weapons procurement was set at CIA's base projection, about 1-percent growth. The rate for machinery imports corresponds to 1986 trends, which is much lower than previous years—the 1985 rate was 7.4 percent—because of the drop in the world price for oil and the associated reduction in Soviet hard currency income.

For the "Gorbachev wins" scenario, machinery imports were increased to 1-percent growth for 1986-90, followed by 3-percent growth in the 1990s. In simulating the short-run sacrifice for long-run gain in consumption, growth of consumer durables for 1986-90 was decreased to 3 percent for 1986-90, followed by an increase to 5 percent in 1991-2000. The cost of weapons procurement remained at about 1-percent growth for the entire period.

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Table B-3 (continued)

	Domestic Trade and Other Sectors	Fuels	Services (less housing)	Industrial Materials	Housing	Agriculture
1986	0.014	0.019	0.020	0.017	0.0075	0.053
1987	0.015	0.021	0.022	0.018	0.0080	0.053
1988	0.016	0.029	0.023	0.020	0.0085	0.053
1989	0.017	0.023	0.024	0.021	0.0090	0.053
1990	0.018	0.024	0.026	0.022	0.0095	0.053
1991	0.018	0.024	0.026	0.022	0.0095	0.053
1992	0.018	0.024	0.026	0.022	0.0095	0.053
1993	0.018	0.024	0.026	0.022	0.0095	0.053
1994	0.018	0.024	0.026	0.022	0.0095	0.053
1995	0.018	0.024	0.026	0.022	0.0095	0.053
1996	0.018	0.024	0.026	0.022	0.0095	0.053
1997	0.018	0.024	0.026	0.022	0.0095	0.053
1998	0.018	0.024	0.026	0.022	0.0095	0.053
1999	0.018	0.024	0.026	0.022	0.0095	0.053
2000	0.018	0.024	0.026	0.022	0.0095	0.053

[a] Retirement rates were set equal to zero after 1996 in the construction sector because all the pre-1986 vintage capital had been retired.

[redacted] 25X1

These growth rates for the 1986-90 period were maintained for the "Gorbachev loses" scenario. For the 1990s, however, growth rates of machinery imports and consumer durables were held at the 1986-90 levels in simulating continued austerity. Without a successful modernization drive, it was assumed that the military would be unable to turn to the civilian sector as planned, and thus, the cost of weapons procurement was set to increase to 2-percent growth per year. [redacted] 25X1

Differences in the modernization parameters among the scenarios are described in the body of this report (see table 2). The capital elasticities for the three scenarios are contrasted in table B-5. [redacted] 25X1

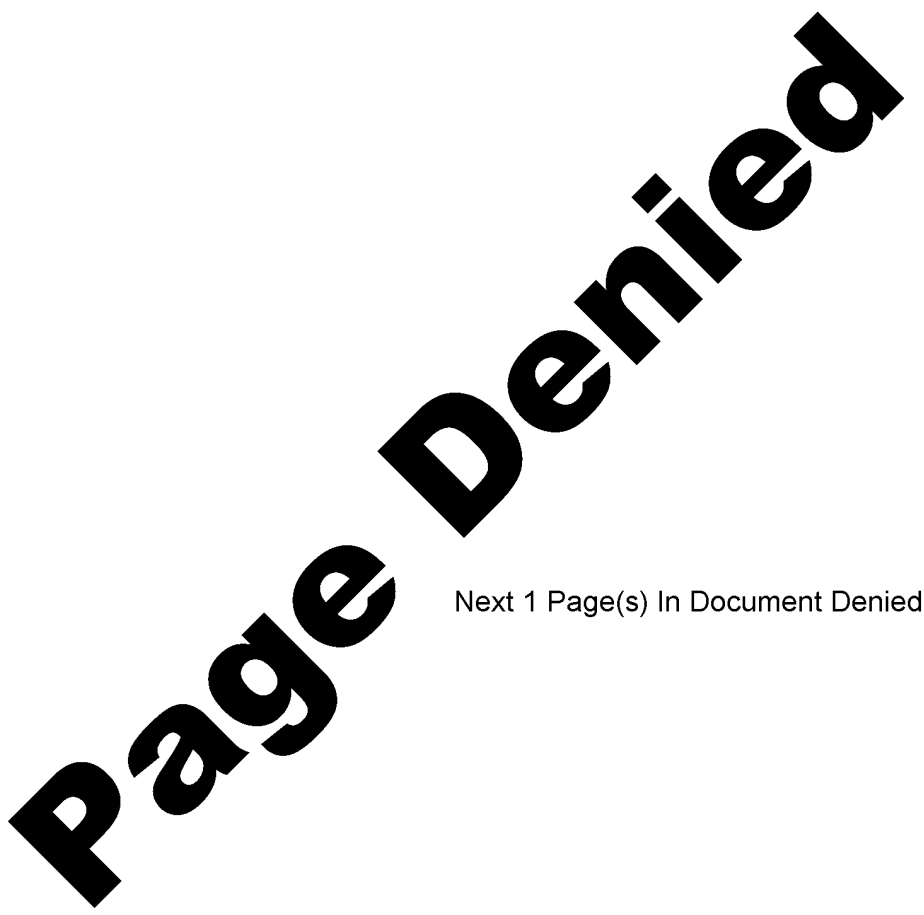

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Table B-5
Capital Elasticities

	Gorbachev Doesn't Matter, 1986-2000	Gorbachev Wins		Gorbachev Loses, 1986-2000
		1986-90	1991-2000	
Machine building	0.523	0.549	0.654	0.549
Chemicals	0.727	0.749	0.836	0.749
Consumer goods	0.422	0.435	0.486	0.435
Construction	0.285	0.294	0.328	0.294
Transportation and communications	0.329	0.339	0.379	0.339
Domestic trade and other sectors	0.175	0.180	0.201	0.180
Fuels	0.039	0.040	0.045	0.040
Electric power	0.891	0.891	0.891	0.891
Services (less housing)	0.197	0.197	0.197	0.197
Housing	0.478	0.478	0.478	0.478
Industrial materials	0.454	0.468	0.523	0.468
Agriculture	0.162	0.162	0.162	0.162

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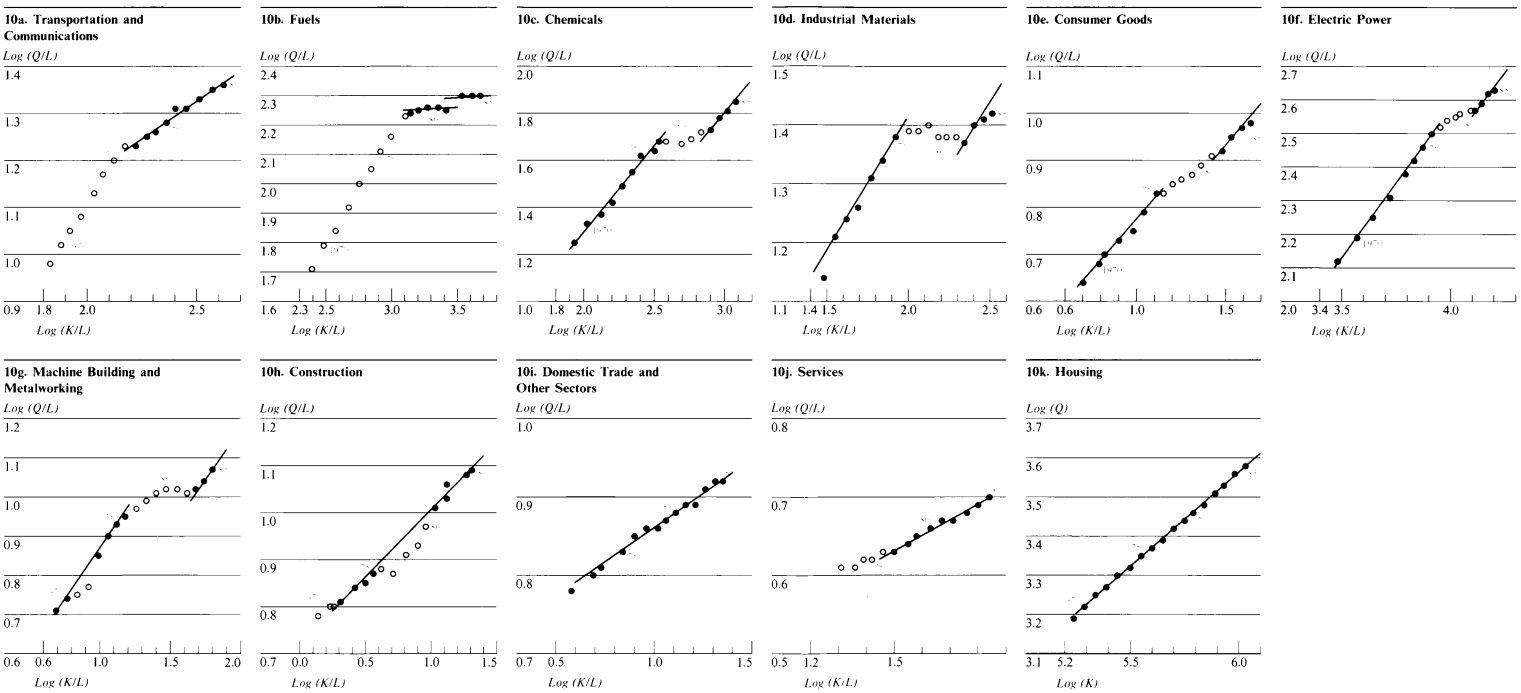
Figure 10
Measuring the Return to Capital in the Soviet Union

Note scale change

—— Regression line fitted using points denoted by closed circles



Note: K is-capital in billions of 1973 rubles.
Q is output in billions of 1982 rubles (factor cost).
L is labor in billions of man-hours.

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